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**AN ANNOTATED BIBLIOGRAPHY OF UNITED STATES AIR FORCE  
ENGINEERING ANTHROPOMETRY — 1946 TO 1988 (U)**

KATHLEEN M. ROBINETTE  
JOY FOWLER

ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY

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HUMAN SYSTEMS DIVISION  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6573



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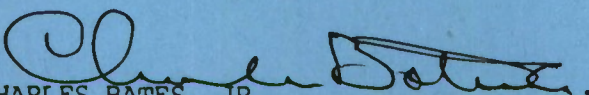
## TECHNICAL REVIEW AND APPROVAL

AAMRL-TR-88-013

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

  
CHARLES BATES, JR.  
Director, Human Engineering Division  
Armstrong Aerospace Medical Research Laboratory



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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This report contains the titles, authors, publication/source information, and the abstracts of 223 technical reports and articles published by the Harry G. Armstrong Aerospace Medical Research Laboratory from 1946 to 1988. It is a detailed document of the scope of the effort of the Air Force in the field of engineering anthropometry to provide the information on human body size and biomechanical characteristics of Air Force personnel required for the development and evaluation of Air Force systems, personal protective equipment, and clothing.					
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## PREFACE

The references for this document were compiled by the Workload and Ergonomics Branch under work unit 71840850. It represents an update of an earlier bibliography, AFAMRL-TR-83-045. In order to prepare this version, the old version was optically scanned and edited, and the new references and indexes were then added to it. The authors would like to thank Mrs. Jane Reese of the Anthropology Research Project, Inc. for preparing the manuscript.



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AN ANNOTATED BIBLIOGRAPHY OF UNITED STATES  
AIR FORCE ENGINEERING ANTHROPOMETRY  
1946-1988

INTRODUCTION

This bibliography is intended to serve as a reference source as well as to document the Harry G. Armstrong Air Force Aerospace Medical Research Laboratory (AAMRL) research in the field of engineering anthropometry. It contains a total of 223 annotated references.

With one exception, each publication listed resulted from studies conducted or sponsored in full or in part by AAMRL. The exception is NASA Reference Publication 1024, An Anthropometric Source Book. This publication is referenced herein owing to its outstanding value and because much of the material and data presented are from the AAMRL Anthropometric Data Bank and from AAMRL supported research. All items in the bibliography are accessible to the public. The reports can be obtained from either the NTIS or DTIC as appropriate by citing the acquisition number (AD \_\_\_\_\_). The inside of the front cover gives the addresses of these agencies. Documents are listed by technical report (TR) number if a TR number has been assigned. Reports without TR numbers are listed by date (month and year). This organization places the references approximately in chronological order. Each entry is numbered sequentially and these numbers are used in the Key Word Index and in the Author Index. These indexes are provided as an aid to the reader in locating references concerning a particular topic.



## THE ANNOTATIONS

1.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	TSEAA-670-9 May 1947 ATI 139 061	Contoured Seat for the Top of an Experimental Rigid Dinghy Box	Hertzberg, H.T.E.

Abstract: The purpose of this paper is to report the adaptation of the rigid dinghy box to contoured seating purposes, and to present metric data on the actual seating surface recommended. This contoured seat should provide the average pilot with both a high degree of seat comfort and with a reasonable ability to extend his legs without undue discomfort. Although several sizes of contoured seats would be necessary to fit all Air Force personnel, the experimental average size described should adequately support the great majority of pilots.

2.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	MCREXD-670-9D June 1949 ATI 67 990	Contoured Seat for Top of an Experimental Rigid Dinghy Box, Report No. 2	Hertzberg, H.T.E.

Abstract: Purpose of this report is to describe some changes in the contour of the original rigid seating surface. These changes were aimed at increasing comfort and reducing the possibility of injury during ejection. Changes consisted of including a groove for the coccyx, moving the position of the lowest point of the seat 1-1/2 inches rearward, and increasing the curvature of certain contour lines. The latter two changes were recommended in order to keep the buttocks more nearly in line with the spinal column during ejection.

3.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	TSEAA-695-58C February 1946 AD 50 569	Principles of Cockpit Seating	Patt, D.I., F.E. Randall & L.F. Griffis

Abstract: This report presents a study of seating requirements for the pilot position in military aircraft. It is one of a series committed to the determination of the fundamental seat and position requirements of flying personnel in the various crew positions in military aircraft. Ninety-five bomber pilots were used as subjects in these experiments. The fundamental requirements of pilot seating in aircraft were determined and were found to be dependent upon cockpit level (vertical distance from horizontal line of vision to level of heel rest) and the type of manual control mechanism used (wheel or stick). Comfort requirements have been determined to be dependent upon the same factors, and also upon seat angulation, differential support of the body over the seat contour, and the positioning of the rudder pedals and control column with respect to the seat.

4.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	MCREXD-695-71D March 1956 ATI 34 088	A Prone Position Bed for Pilots	Colgan, J.W. & H.T.E. Hertzberg

Abstract: This report describes the development of a prone position bed for pilots, and the results of comfort tests thereof. This bed consists of specially-shaped sides to which a length of nylon netting is affixed. Special controls, footrests, net tension adjusting cams for abdominal support, chin rest and head support are required as adjuncts to the bed proper. Comfort tests of the bed were conducted with a series of 19 subjects who represented over 95 percent of USAF personnel in both stature and weight. The bed was adjusted to each subject for utmost comfort. The major adjustments were for stature, abdominal support, and arm position on the controls.

Eighteen subjects lay on the prone position bed for eight consecutive hours each, or longer, and one subject lay four hours. After formal tests were completed, two members of the test team lay on the bed for 12 hours each.

5.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	TSEAA-695-73 December 1946	Angular Fields of View Through the A-1 Gunsight in the P-80 Cockpit Modified for Ejection	Hertzberg, H.T.E.

Abstract: This report presents the results of a study of the angular field of view in the P-80 cockpit at specified eye-to-pivot distances. Installation of the ejection seat in this aircraft forced the lengthening of cockpits. As a step in providing optimal gun sight placement, the Armament Laboratory requested a study of the angular fields of view available to the pilot at specified eye-to-sight pivot distances 30, 35, 40, 45, and 50 inches.

Four representative pilots wearing standard equipment were employed in measuring the angular fields of view. Their average angular fields of view were found to range from 10.2 degrees vertically and 22 degrees laterally at the 30-inch distance. The only important factors limiting the field of view were the width of cockpit and canopy, and the size of the crash helmet. Other variables such as personal equipment and body size were found to be of no importance in limiting their fields.

6.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	MCREXD-695-80 November 1948	Inhabited Wing Tip Turret	Hertzberg, H.T.E.

Abstract: The purpose of this report was to describe some subjective impressions and objective measurements observed during flight in the inhabited turret installed on the right wing of a B-17 aircraft (a project sponsored by



Armament Laboratory). Eight representatives of the Aero Medical Laboratory flew in this turret. Their opinions were unanimous regarding the following subject sensations:

- a. The location was livable and comfortable from the physiological standpoint, with no sense of nausea or uneasiness from the most violent maneuvers.
- b. Visibility was greatly superior to that of any other situation.

Measurements showed that the highest vertical accelerations the pilot could produce in the wing tip turret by means of the most violent maneuvers were of the order of only plus 4g, while ordinary maneuvers produced only plus 2g. In landing, an instantaneous value of plus 8g was recorded. These forces, however, are not unique to the wing tip position and are easily tolerable.

Certain minor sources of discomfort were found including high noise level which interfered considerably with intercommunication, and also high temperature during taxiing in the hot summer sun. Ventilation and temperature were satisfactory during flight.

7.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	MCREXD-695-82 April 1949 AD 70 599	Comfort Tests of the Pulsating Seat Cushion and Lumbar Pad	Hertzberg, H.T.E.

Abstract: The tests were conducted using 21 subjects who represented approximately 88 percent of Air Force personnel in weight and 95 percent in stature. The period of sitting varied from four hours, 55 minutes to eight hours, with an average of six hours, 45 minutes. One group of subjects sat on the non-pulsating cushion an average of two hours, 40 minutes before starting the pulsations. The second group had the cushion pulsating through the test. Apparently the latter group was able to sit somewhat longer under these conditions--approximately four hours on the average--before reaching the peak of discomfort, although this cannot be considered definitely established. Subjects periodically expressed their degree of discomfort on a five-step scale ("absent, mild, moderate, severe, unbearable").

Test results indicate that this cushion does help to relieve buttock discomfort, but does not eliminate it.

8.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	MCREXD-720-143 October 1949 ATI 122 733	Hammock for the B-36 Airplane	Hertzberg, H.T.E. & G.S. Daniels

Abstract: This report describes a rapidly demountable net sleeping hammock for intermittent use by the stand-by crew in the forward compartment of the B-36 airplane.

9.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	AAF-TR-5501 June 1996 ATI 25 419	Human Body Size in Military Aircraft and Personal Equipment	Randall, F.E., A. Damon, R.S. Benton & D.I. Patt

Abstract: This report deals with the relation of human body size to military aircraft and equipment. It contains the necessary data and instructional material to guide the designers of aircraft and associated flying equipment in the proper use of anthropometry, as it applies to AAF flying personnel. The functional man is fully described and the spatial requirements of his personal equipment are evaluated. Finally, the complete functional man is considered in his air crew position and as an integral part of the functional aircraft.

10.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	MCREXD-45341-4-5 March 1950 ATI 74 410	The Center of Gravity of a Fully Loaded F-86 Ejection Seat in the Ejection Position	Hertzberg, H.T.E. & G.S. Daniels

Abstract: The purpose of the study was to determine the center of gravity (c.g.) of the F-86 Ejection Seat in ejection position when loaded with a pilot wearing full flying equipment. The c.g. of the seat was measured by suspension in two positions under full load. It was shown that the c.g. varies for each individual according to size, weight, and body build, and also for the position of the subject on the seat. Thus, the c.g. of an individual may be thought of as an area rather than a point. The average c.g. of nine subjects was located at a point 13-3/16 inches from the back of the seat and 15-7/8 inches from the bottom of the seat pan. For the lighter than average men, in this series the average c.g. was located approximately 1/4 inch aft and 1/4 inch below that point. The c.g. of the loaded seat, thus, travels roughly 7/8 inch along a line whose angle is approximately 30 degrees from the seat pan.

11.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	September 1948	Post War Anthropometry in the Air Force	Hertzberg, H.T.E.

Source: American Journal of Physical Anthropology, 6:3, 363-371,  
September 1948.

Abstract: A resume of activities current in 1948 in the Anthropology Branch.



12. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
June 1952	Air Force Anthropology in 1950	Hertzberg, H.T.E. & G.S. Daniels

Source: American Journal of Physical Anthropology, 10:2, 201-208, June 1952.

Abstract: This paper presents an account of research underway, emphasizing its breadth and diversity.

13. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
June 1952	Applied Anthropometry of the Hand	Daniels, G.S. & H.T.E. Hertzberg

Source: American Journal of Physical Anthropology, 10:2, 209-215, June 1952.

Abstract: This paper describes briefly the development of the stick grip used in controlling aircraft, and the research on hand shape that underlies a new design of stick grip.

14. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
TN WCRD 52-81 September 1952 AD 99 784	Review of Escape Hatch Sizes for Bailout and Ditching	White, C.B., P.J. Johnson & H.T.E. Hertzberg

Abstract: The purpose of this study was to review wartime specifications of escape hatches in terms of current and experimental flying equipment. Seven subjects ranging in height, weight, and shoulder width from the 5th percentile to the 95th percentile of Air Force flying personnel (1950 Survey) were used in most of these tests. Three combinations of clothing and equipment were involved. The mock-up for the tests consisted of a plywood panel having slats. The panel could be positioned in the horizontal, vertical, or any intermediate plane to simulate an escape hatch in any portion of the aircraft, while the opening could be adjusted to any desirable size from 17 inches to 36 inches square. These tests demonstrated that the present standard sizes of 20 by 31 inches for the side hatch and 20 by 29 inches for the bottom hatch were adequate for use with either the current equipment or the newer experimental clothing, providing no tunnel is involved or the access area is not obstructed. Furthermore, the standard size of the top hatch should be increased to 22 by 22 inches, and there should be a step or ledge not more than 45 inches below the lowest edge of the hatch to give additional leverage to shorter crew members.

15. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 52-321 September 1954 AD 47 953	Anthropometry of Flying Personnel - 1950	Hertzberg, H.T.E., G.S. Daniels & E. Churchill

Abstract: Body size data for 132 measurements of over 4,000 Air Force flying personnel are presented. Organization of the survey is briefly discussed, and the techniques of measurement are illustrated by photographs for the benefit of other anthropologists. Both diametral and surface measurements are included. Dimensions are given in both centimeters and inches.

A description of the statistics and an explanation of their use are given with some discussion of certain statistical shortcuts employed in the reduction of the data. The tabulations include range, mean, standard deviation, coefficient of variation, and 25 selected values from the 1st to the 99th percentile. Means and standard deviation values for each dimension are also given for nine subgroups based on flight duties.

A Glossary and Bibliography are included.

These data are presented for use by the designers of aircraft, clothing, and equipment.

16. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
TN WCRD 53-7 December 1952 AD 10 203	The "Average Man"?	Daniels, G.S.

Abstract: The tendency to think in terms of the "average man" is a pitfall into which many persons blunder when attempting to apply human body size data to design problems. Actually, it is virtually impossible to find an "average man" in the Air Force population. This is not because of any unique traits of this group of men, but because of the great variability of body dimensions which is characteristic to all men. It is the intent of this Technical Note to point out and explain some of the factors that lead to the difficulties arising from the use of "average" dimensions and to indicate to some extent how they may be avoided.

The data on which this Technical Note is based are the results of the Air Force Anthropometric Survey of 1950. There is, however, every reason to suppose that conclusions similar to those reported here would have been reached if the same type of analysis had been applied to body size data based on almost any group of people.



17. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 53-12 July 1953 AD 20 542	Anthropometry of WAF Basic Trainees	Daniels, G.S., H.C. Meyers & S. Worrall

Abstract: Body size data for 63 dimensions of 852 Women's Air Force basic trainees are presented for use by the designers of Air Force equipment.

The statistics reported for each measurement include the mean, standard deviation, coefficient of variation, standard errors of these statistics, range, and selected percentiles from the 1st to the 99th. In general, these statistics are reported in both the metric and English values.

A complete description of the anthropometric techniques used is presented.

18. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 53-14 May 1953 AD 16 748	Nomographs of Head Measurements	Churchill, E. & G.S. Daniels

Abstract: To achieve the optimum design of equipment intended to fit the wearer's head closely, a knowledge of the interrelationships between the more important head dimensions is necessary.

This report provides such information in the form of two nomographs for determining the most accurate estimate for each of 12 head dimensions based on known values of head length and head breadth, and head breadth and head circumference.

19. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 53-49 July 1953 AD 20 717	Anthropometry of Male Basic Trainees	Daniels, G.S., H.C. Meyers & E. Churchill

Abstract: Body size data for 60 measurements of over 3,000 Air Force male basic trainees are presented for use by aircraft and equipment designers.

The statistics reported for each measurement are: the mean, standard deviation, coefficient of variation, standard errors of these statistics, range, and selected percentiles from the 1st to the 99th. In general, the statistics are reported in both the metric and English values.

A complete description of the anthropometric techniques used is presented.

20. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 53-53 March 1953 AD 13 206	Development of a Workspace Measuring Device	Dempsey, C.A.

Abstract: This technical report describes a Workspace Measuring Device which was developed to determine the maximum, minimum, and optimum space requirements of Air Force pilots when seated in the cockpit situation, and to simulate in the laboratory existing or proposed cockpit designs with an eye to proper space utilization.

21. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 54-6 April 1954 AD 30 282	Ground Study of the Non-Ejection Methods of Escape from B-47B Aircraft	Morrison, N.K. & L.A. Schafer

Abstract: This report covers Phase I, Ground Study of the Non-Ejection Methods of Escape from B-47B Aircraft. Because the cabin space available to the crewmembers is so limited, it was necessary to make a thorough investigation of those body positions and movements at the disposal of the crew when evacuating the aircraft. This study, done at Wright-Patterson Air Force Base, led to the establishment of optimum procedures to be followed by each man when leaving his station and reaching the possible escape exits, and the most feasible body positions for leaving the aircraft.

The personal equipment worn by each subject during these tests included both winter and summer flying clothing. Each procedure was performed with and without the A-1 survival kit.

Time studies covered crew escape through the central hatch, with and without the use of an escape bracket, and through the crawlway to the bomb bay. Eight crews participated in the central hatch tests and six crews in the bomb bay tests. Ground studies of egress through the navigator's ditching hatch and canopy were limited to the timing of individuals making personal leads disconnects and standing at their stations. The feasibility of using these exits will have to be determined during the Air Study Phase.

Analysis of the data thus accumulated indicates that the optimum method of non-ejection escape from this aircraft is through the central hatch in a feet-first, facing-aft position utilizing the Barto escape bracket. It must be stressed that the data are based on the tests made with the aircraft on the ground and in the absence of factors that would cause a flight emergency necessitating bailout.



22.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	WADC TR 54-520 August 1956 AD 110 573	The Anthropometry of Working Positions	Hertzberg, H.T.E., I. Emanuel & M. Alexander

Abstract: A sample of 40 adult males has been measured to ascertain new body size data for various representative working positions. Measurements were taken with the body in the standing, kneeling, crawling, and prone positions. Problems met in developing procedures for an anthropometry describing working positions are discussed, along with possible approaches for data gathering.

23.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	WADC TR 54-548 August 1955 AD 81 792	Arm Strength at Selected Degrees of Elbow Flexion	Hunsicker, P.A.

Abstract: A selected summary of the strength testing literature forms the first part of this study. This is followed by a listing of the modifications that had to be made on the Kinematic Muscle Study machine as a result of exploratory testing. The major portion of the investigation is concerned with the results of testing 55 young men on 60 arm strength tests in the sitting position and 60 in the prone position. Percentile tables and figures depicting arm strength in relation to degrees of elbow flexion are included. Recommendations for further use of the Kinematic Muscle Study machine are offered.

24.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	WADC TR 55-159 July 1955 AD 87 895	Space Requirements of the Seated Operator	Dempster, W.T.

Abstract: The structure of the limb joints and the range and type of their motions were studied on cadaver material, with supplementary work on living subjects, in order to clarify geometric, kinematic, and engineering aspects of the limb mechanism. Plans for the construction of manikin joints which showed normal ranges of limb movement were developed from this information. Specifications were also worked out for drafting board manikins which show correct limb ranges for seated postures. Subjects comparable to the model physique of Air Force flying personnel and highly selected small samples of muscular, thin, and rotund builds supplied information on the range of possible hand and foot movements which was consistent with the seated posture. Maximum dimensions of the work space for seated individuals were determined; a study of the kinematic factors involved permitted an evaluation of the potential utility of different regions within reach. Eight cadavers were dismembered to provide data on such physical constants as mass of parts, segment centers of gravity, density, and moments of inertia. This work was supplemented by data on the distribution of body bulk in the living subjects studied. Applications of the

above information to analyses of horizontal push and pull forces in terms of couples permitted an evaluation of the effectiveness of body mass, leverages, and support areas.

25. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 54-30 May 1958 AD 155 622	Annotated Bibliography of Applied Physical Anthropology in Human Engineering	Hansen, R. & D.Y. Cornog

Abstract: This volume contains condensations of 121 reports in the field of Applied Physical Anthropology. A majority of the annotations are grouped under three headings: Anthropometry, Biomechanics, and Comfort; a few are included in a general group. Working data and important illustrations are quoted directly from the original papers in most cases. A complete index is arranged by author as well as by subject. An additional list of reports (not annotated) is included as background material. Two appendices containing relevant commentary on Seating Comfort and Anthropometric Dummies are also included.

26. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 56-364 February 1957 AD 118 003	Linear Distance Changes over Body Joints	Emanuel, I. & J.T. Barter

Abstract: Linear distance changes over the body surface resulting from various joint movements were studied on a series of 30 young men. The following joints and joint complexes were studied: head and neck, shoulder, elbow, wrist, fingers, trunk, hip, knee, and ankle. Summary statistics and design values are presented for 48 linear distance changes measured over these joints.

While there are usually definite and significant changes in bodily dimensions resulting from joint movements, these changes are generally fairly constant in magnitude. At the same time, the changes are mostly unrelated to body size. The information is designed for application to close-fitting altitude clothing which must provide both physiological protection and body mobility. In addition, these data can serve as a guide for determining easement factors for more commonplace types of clothing.

27. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 56-365 April 1959 AD 130 917	A Height-Weight Sizing System for Flight Clothing	Emanuel, I., M. Alexander, E. Churchill & B. Truett

Abstract: This report presents a height-weight sizing system for use by designers and fitters of flight clothing, The observations and recommendations reported here are based on a reanalysis of the body size data of the 1950 Anthropometric Survey of Air Force flying personnel.

This reanalysis consisted of selecting pairs of dimensions and correlating these with other dimensions important in clothing design. Among the pairs studied, height and weight have been chosen as basic sizing dimensions. In addition to presenting the methodology used in the present problem, the practical and statistical problems of developing a sizing system are thoroughly discussed. Finally, tables of body dimensional data are presented for several basic size programs (6-size, 8-size, 9-size, and 12-size), since the number of sizes varies with the type of garment. These tables include fitting charts, estimated procurement tariffs, design ranges, mean values for size groups, and bivariate tables for height and weight with size categories marked off for each program. The choice and application of these programs are discussed in detail.

Descriptions of the selected body dimensions are included.

Advantages of the height-weight system include improved fit; fewer alterations; minimal adjustability; and simplified procurement, distribution, and fitting procedures.

28. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 56-366 August 1956 AD 97 205	A Statistical Comparison of the Body Typing Methods of Hooton and Sheldon	Dupertuis, C.W. & I. Emanuel

Abstract: Body type component ratings made according to the standards of Hooton and Sheldon were compared in a sample of 500 Air Force flying personnel. Correlation coefficients for the two ratings of the same components are as follows: first component, 0.8; second component, 0.83; third component, 0.86; gynandromorphy, 0.66; and dysplasia, 0.05. On the average, the Hooton ratings were 0.51 unit more than the Sheldon ratings for the first component, 1.00 unit less for the second component, and 0.67 unit more for the third component. For all three primary components, identical ratings were given in 33.7 percent of the cases, while an absolute deviation of one unit occurred in 50.3 percent of the cases, a deviation of two in 15.5 percent of the cases, and a deviation of three units occurred in 0.6 percent of the cases. Six subjects were given identical body type ratings according to both systems. Regression equations are given for the relationships between the primary components, but the standard errors of estimate are too high to permit accurate equation of body type assessments on the same individual.



29. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 56-367 August 1956 AD 97 206	A Study of Human Weight Lifting Capabilities for Loading Ammunition Into the F-86H Aircraft	Emanuel, I., J.W. Chaffee & J. Wing

Abstract: The weight lifting ability of a sample of 19 young men was studied. The lifting procedures were standardized and controlled in order to simulate a precise task, that of loading ammunition into the F-86H aircraft. An ammunition case with varying amounts of weight was lifted to platforms one, two, three, four, five, six, and seven feet above the floor.

All subjects could lift the case in the prescribed fashion up to and including five feet above the floor. Only nine subjects could properly lift to six feet, and only one individual performed at the seven foot platform. Suggested maximum weights required for actual lifting tasks are presented. Based on the 5th percentile values, they are as follows: one foot - 142 pounds; two feet - 139 pounds, three feet - 77 pounds; four feet - 55 pounds; and five feet - 36 pounds.

30. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 56-404 February 1957 AD 110 548	A Comfort Evaluation of a Form-Fitting High Altitude Helmet	Alexander, M. & H.T.E. Hertzberg

Abstract: This report describes comfort tests on an experimental pressure helmet assembly, consisting of an outer rigid shell and an inner compressible, form-fitting liner of polyurethane foam. Seventy-two subjects were used, of whom 21 were rated military pilots. A number of testing techniques and fabrications requirements for comfort and acceptability are discussed, and their applicability to most forms of headgear, especially those using compressible liner material, is indicated.

31. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 56-458 December 1956 AD 97 216	Body Dimension Changes During Basic Training	Meyers, H.C., G.S. Daniels, E. Churchill & N.S. Roelke

Abstract: Changes during basic training in the body dimensions of approximately 200 airmen and a similar number of airwomen were measured. Eight circumferences, weight, and stature were measured weekly during each of the first four weeks and during the eighth and twelfth weeks of training.

The results of data were analyzed in the hope that changes in proper clothing size which occur during the training period could be predicted in advance. Variability in the changes was found to be too large, and the relationships

among the changes and the airmen's original dimensions too poor to permit useful predictions.

A complete resume of the results of the investigations is presented here for the guidance of personnel concerned with the design and the issuance of clothing for and to basic trainees.

32. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 56-459 June 1956 AD 97 217	Bodily Dimensions of the Older Pilot	Fry, E.I. & E. Churchill

Abstract: A comparison of 132 body dimensions on selected groups of older and younger pilots is presented. These groups are compared on their mean values of these dimensions, and more intensively on five percentile distributions of 20 dimensions.

When differences exist between the groups, an explanation has been sought in terms of the physical process of aging, and in selection.

Most of the older-younger pilot differences are small and statistically non-significant, but a few are of great importance, and should be taken into account in designing Air Force equipment.

33. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 56-599 December 1956 AD 110 589	A Sizing System for High Altitude Gloves	Barter, J.T. & M. Alexander

Abstract: This report presents the rationale for and procedures followed in the development of a sizing program for high altitude gloves. This program is based on four divisions of hand circumference, each subdivided into three divisions of hand length making a total of 12 sizes. A selected sample of 100 hands was measured to provide the 31 dimensions presented for design purposes. Summary statistics, regression equations, design dimensions, and a procurement tariff are presented in various tables throughout the report.

The results of a fit-test of two differing styles of gloves sized according to this program indicate that a high percentage of personnel can be fitted adequately in their indicated size. Detailed instructions for determining the indicated size of gloves are also included.

34. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 56-621 June 1957 AD 110 629	Metrical Relations Among Dimensions of the Head and Face	Churchill, E. & B. Truett

Abstract: Correlation data for the head and face dimensions of two groups of USAF personnel are presented. These data extend the useful information about these dimensions into the areas in which two or more dimensions are considered simultaneously. Forty-one dimensions of flying personnel, based on a sample of over 4,000, and six dimensions of WAF trainees, based on a sample of 852, are reported. In addition to a presentation of the data, the report discusses the utility of correlational statistics in the design of personal equipment and describes the procedures used in obtaining these data.

Coefficients of correlation for the 820 pairs of flying personnel data and the 15 pairs of WAF data are given. Multiple correlation coefficients for each dimension and selected pairs of dimensions for the flying personnel are also given. Regression equations for estimating one dimension from values of another are listed for most pairs of flying personnel dimensions which are at least moderately well correlated. About 70 bivariate frequency tables are presented.

No useful summary of this large body of statistics can be made since it is the individual data which are of importance.

35. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 57-197 April 1957 AD 118 161	WAF Trainee Body Dimensions: A Correlation Matrix	Churchill, E. & K. Bernhardt

Abstract: Correlation coefficients expressing the degree of relationship between the 1830 pairings of 61 WAF basic trainee body dimensions are presented in this report. Slightly over two thousand multiple correlation coefficients expressing the degree of relationship between each of these dimensions and 36 pairs of them are also given. Regression equations for estimating all other dimensions from specified values of stature, weight, and stature and weight together are listed. Values computed from most of these equations are tabulated for the most frequently occurring values of stature, weight, and stature-weight combinations. This correlation material supplements the basic dimensional data given in Anthropometry of WAF Basic Trainees, WADC TR 53-12, and, with these data, provides a basis for the planning and execution of design programs involving the body dimensions of these individuals.



36.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	WADC TR 57-19S April 1957 AD 118 162	Nomograph of the Hand and Its Related Dimensions	Churchill, E., A. Kuby & G.S. Daniels

Abstract: The design of equipment which must fit closely a part of the user's body calls for a knowledge both of the actual dimensions of this part of the body and the interrelationships among these dimensions.

This report brings together both types of information for the hand. Dimensional data for the hands of both male and female USAF personnel are summarized in tabular and graphic form. Intensities of the interrelationships within each of the two groups of dimensions are given in the form of tables of correlation coefficients. A series of tables supply estimates of the other dimensions for the appropriate ranges of values of hand length, hand breadth at metacarpale, hand breadth at thumb, and fist circumference.

Nomographic charts are presented for estimating the related dimensions for all likely combinations of values of hand lengths and breadths for both USAF flying personnel and WAFs.

The basic data used for the men are those obtained from a survey of USAF flying personnel; for women, the data are those obtained from a survey of WAF basic trainees. Data obtained from other surveys of military personnel are summarized; these data suggest the applicability of the tables and charts presented here to the design of articles intended for almost any group of USAF personnel.

37.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	WADC TR 57-260 April 1957 AD 118 222	Estimation of the Mass of Body Segments	Barter, J.T.

Abstract: The present study is concerned with the reanalysis of the data concerning the mass of body segments published in WADC TR 55-159, Space Requirements of the Seated Operator, Dempster, 1955, and in The Center of Gravity of the Human Body as Related to the Equipment of the German Infantry, Braune and Fischer, 1889.

Regression equations for computing the mass of body segments for any known body weight are presented along with data on estimated weights of body segments of Air Force flying personnel.

38.	REPORT NUMBER/DATE	TITLE	AUTHOR(S)
	WADC TR 57-311 August 1957 AD 131 028	A Statistical Evaluation of Joint Range Data	Barter, J.T., I. Emanuel & B. Truett

Abstract: This study reanalyzes the data concerning the range of motion of human body joints published in WADC TR 55-159, Space Requirements of the Seated Operator, by W.T. Dempster. The reanalysis is intended to present the information in a form more applicable to Air Force design problems. An analysis of variance of 43 joint movements for four subgroups originally selected on the basis of physique revealed that 12 body movements (28 percent) were related to physique. The subgroup statistics were combined to yield summary statistics for the total sample of 39 young men. Design ranges were derived from these total group values. Descriptions and illustrations of joint movements are included.

39. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 57-432 July 1957 AD 130 912	Height-Weight Sizing and Fit-Test of a Cutaway G-Suit, Type CSU-3/P	Emanuel, I. & M. Alexander

Abstract: Body size data from the 1950 Air Force Anthropometric Survey have been reanalyzed to yield a statistical sizing program based on height and weight. This six-size program was incorporated into the Type CSU-3/P Cutaway Anti-G garment, which was tested from the standpoint of fit and comfort. Suit selection was accomplished simply by asking each subject his height and weight. Of 73 subjects fitted, 72 were comfortably accommodated by the size indicated by height and weight values. It is concluded that this sizing procedure will result in the saving of time and money because of the ease of fitting, reduction of individualized tailoring, and simplification of procurement.

40. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 57-586 December 1957 AD 131 089	A Study of Muscle Forces and Fatigue	Hunsicker, P.A.

Abstract: The first phase of the research deals with the strength test results taken on 30 subjects covering 120 strength tests. The subjects were seated in a simulated pilot-seat and six movements were tested. The results are presented in percentile tables and graphic form. The next part of the study involves data on 25 subjects who were tested to determine the amount of strength possible in wrist pronation and wrist supination. The final phase of the research gives information on the strength decrement over a 42-hour period in which the subjects were tested hourly. Several recommendations are offered.

41. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
April 1958	Anthropology and Space Research	Hertzberg, H.T.E.

Source: Anthropology in the Armed Services: Research in Environment, Physique and Social Organization, L. Dupree, Editor, Published by the Social Science Research Center, Pennsylvania State University, University Park, Pennsylvania, April 1958.

Abstract: This paper discusses the contributions of engineering anthropology in space exploration, pointing out that the brilliant advances into outer space 500 miles up are based on the anthropological developments in oxygen masks, pressure suits, gloves, helmets, and other protective equipment. The problem of human survival in an environment offering no oxygen, no water, no atmospheric pressure, and no gravity is considered, with a discussion of the means of work output in such conditions. Suggestions are made for preliminary ground research on those problems, which would enlist the aid of academic as well as military anthropologists.

42. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 58-67 February 1958 AD 150 964	Stereophotogrammetry as an Anthropometric Tool	Hertzberg, H.T.E., C.W. Dupertuis & I. Emanuel

Source: Photogrammetric Engineering, 942-947, December 1957.

Abstract: This paper briefly reviews previous biological applications of stereophotogrammetry, and outlines with illustrations the present procedures used to draw human body contours at 1/2 inch intervals. It compares the dimensions derived from plotted profiles with those taken by hand of the subjects themselves. It discusses the utility of stereo data for special anthropometric purposes, and mentions further applications for other biological sciences.

43. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 58-505 March 1959 AD 213 604	Anthropometric Sizing and Fit-Test of the MC-1 Oral-Nasal Oxygen Mask	Emanuel, I., M. Alexander & E. Churchill

Abstract: A sizing program for oral-nasal oxygen masks, based on total face length and lip length, has been developed through a reanalysis of the 1950 USAF Anthropometric Survey head and face data. Face forms, based on this sizing program, have been constructed for use in the preparation of such masks. The MC-1 Oxygen Mask, an oral-nasal, pressure-demand type mask, has been fabricated in accordance with this sizing system and through the use of these face forms. In the fit-tests, 149 of 150 subjects fit-tested were satisfactorily fitted in their indicated sizes.



This report includes a discussion of the theoretical and practical aspects of the sizing procedure. Design limits and related statistical material and suggested procurement tariffs for each of the six sizes proposed are given. The MC-1 mask is described, and the fit-test procedure and results are presented.

44. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADC TR 59-165 April 1959 AD 219 894	A Supine Seat for High- Stress Testing of Primates	Eisen, L. & R.S. Zeigen

Abstract: This study summarizes the design rationale of a supine seat and restraint harness, with surrounding enclosure, for high stress bioscience experiments with a *Macaca cynomolgus* monkey (*Macaca iris*). This configuration is intended for test under various abnormal stresses, including high g centrifuge runs. Testing and feeding of the subject in the enclosure will be accomplished to determine his reaction to these stresses. With minimum modification, the Macaque supine seat and restraint harness could accept any primate for ground tests or bioexperiments in space flight. A brief description of an earlier supine test seat and restraint harness for low-stress experiments using a squirrel monkey is included.

45. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADD-TR-60-18 January 1960 AD 234 005	The Anthropometry of Body Action	Dempster, W.T.

Source: Annals of the New York Academy of Science, 63:4, 559-585, November 1955.

Abstract: The author discusses the principles of investigating dynamic anthropometry in relation to movement patterns of the human body.

46. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADD-TR-60-19 January 1960 AD 233 711	Some Contributions of Applied Physical Anthropology of Human Engineering	Hertzberg, H.T.E.

Source: Annals of the New York Academy of Science, 63:4, 616-629, November 1955.

Abstract: The author defines human engineering as "fitting the machine to the man and keeping him functioning with efficiency, with safety, and without discomfort, in any environment," and presents three studies as examples of the contributions that can be made by physical anthropology to human engineering.

Under the first example, the author condemns the use of "average data," and summarizes the engineering use of the percentile curve as a tool to improve the sizing of workspace, clothing, or personal-protective equipment. The second example outlines the use of muscle-strength data in improving human safety and ease of machine operation. The third presents an attempt to answer the question, "What happens to the buttocks when you sit on them?" A map of the buttock sitting areas is shown, with a general description of cushions designed according to theoretical and experimental findings.

47. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
WADD-TR-60-631 December 1960 AD 251 939	A Head Circumference Sizing System for Helmet Design: Including Three- Dimensional Presentation of Anthropometric Data	Zeigen, R.S., M. Alexander & E. Churchill (Consultants: I. Emanuel & S. Velsey)

Abstract: A system for the sizing and design of rigid and semirigid helmets based on a single key dimension, head circumference, is described. Anthropometric data largely obtained in the 1950 survey of Air Force flying personnel were analyzed. The three sizing programs discussed in terms of tabular data are also referred to in terms of headforms or three-dimensional representations of these data. These programs are: a six-size program based on mean values, a three-size program based on mean values, and a six-size program for helmet liner problems.

This report includes an account of the historical development of sizing systems, programs, and resultant headforms in the Air Force; a detailed statement concerning the design rationale and statistical concepts used; comprehensive tables needed by the designer for all sizing programs discussed; a statement as to sculpturing techniques and problems; and a comment on preliminary validation results and on the overall design-material-sizing concept.

Appendices include a glossary of significant terms, descriptions of selected head and face dimensions, a detailed discussion of statistical concepts and formulae referred to in the report, and tables of comparative four- and six-size programs based on the key dimensions of head length and head breadth.

48. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
ASD-TR-61-89 April 1961 AD 258 564	The Anthropometry of the Manual Work Space for the Seated Subject	Dempster, W.T., W.C. Gabel & W.J.L. Felts

Source: American Journal of Physical Anthropology, 17:4, 289-317, December 1959.

Abstract: The anthropometry of the manual work area was approached by an indirect method using photo records of time exposures showing the motions of a tiny neon lamp as the hand grip. The records of 22 male subjects were analyzed for three sets of motions involving the forward-directed hand and different grip orientations. Techniques were developed for defining the limits of the space within reach relative to the mid-sagittal junction of the seat and chair back. Graphical records of the different hand-range spaces were grouped and compared to bring out variability data, the extent of right-left hand overlap, regions of maximum hand flexibility, mean hand positions, etc. The data have been discussed in relation to the geometry of the more effective hand positions and in relation to practical problems of workspace design.

49. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
ASD-TR-61-90 July 1961 AD 263 715	Dynamic Anthropometry Working Positions	Hertzberg, H.T.E.

Source: Human Factors Bulletin, 2, 147-155, August 1960.

Abstract: This paper provides a review of the principles and procedures of workspace design for engineers. It emphasizes that human body size (anthropometry) and muscle force capability (biomechanics) are both essential for the efficient sizing of equipment. The proper method of workspace design, the "design limits concept," is described; and the fallacy of the "average man" concept is demonstrated. General methods of gathering body size and strength data are outlined, and major information sources noted. The author's ideas on human muscle strength in the weightless state are included.

50. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
ASD-TR-61-206 December 1961 AD 280 049	Nylon Net Seat for a Modified RB-57 Aircraft	Hertzberg, H.T.E.

Abstract: A lightweight, adjustable, easily demountable net seat for persons who must operate in cramped quarters is described. Tests lasting for more than a year in a modified RB-57 have shown the seat to be fully satisfactory. Design drawings and photographs of the method of installation are included.

51. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
ASD-TR-61-599 October 1961 AD A027 345	Anthropometric Data Presented in Three- Dimensional Forms	Alexander, M., R.S. Zeigen & I. Emanuel

Source: American Journal of Physical Anthropology, 19:2, 147-157, June 1961.



Abstract: The Anthropology Section, Aeronautical Systems Division, has used new as well as standard approaches in the attempt to translate anthropometric data into three-dimensional forms. Basic anthropometric data must be interpreted for the designer and engineer prior to their application to practical problems. One recognized method of presentation is summing each dimension under its mean, standard deviation, and percentiles. This approach has been proven quite acceptable for workspace situations concerned with gross measurements. On the other hand, considerable confusion exists among designers and engineers when it comes to handling anthropometric data for items of close-fitting protective equipment (e.g., pressure suits, oxygen masks, and helmets). In the past, various head and body forms have been fabricated to provide the designers with more concrete expressions of anthropometric data. Recent efforts along these lines have led to the development of new three-dimensional forms, some for general applications and others for specific problems. All of the current approaches employ key dimensions chosen to determine size ranges. Items included under this program are (1) a series of face forms (key dimensions are total face length and lip length); (2) two series of head forms (both using head circumference as the key dimension); and (3) a series of body manikins (based on height and weight). The special set of face forms has been used to size a new lightweight oxygen mask; the two head form series are in use for the experimental sizing of various helmets, and the body manikins are being fabricated to represent a range of body sizes using a height-weight system for flight clothing. The design rationale on which these forms are based and the difficulties encountered in sculpturing them to dimension are discussed.

52. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TDR-62-111 September 1962 AD 291 412	X-Ray Anthropometry of the Hand	Vicinus, J.H.

Abstract: Presented in this report is a comprehensive descriptive summary of the roentgenographic anthropometry of the hand. The 253 subjects chosen for measurement have been selected so as to be representative of the Air Force population in hand length and hand breadth.

Summary statistics for 24 lengths and 20 breadths for both the left and the right hands are presented. Also included in the report are complete inter-correlation matrices for both hands indicating the degree of interrelationship between the 44 dimensions.

Analysis of the data indicates that, in general, the right hand tends to be longer and broader than the left with the right hand showing slightly greater variability in length and less variability in breadth than the left. The lowest correlations occur in the relationships between length and breadth dimensions, and the highest are to be found within the length dimensions of each of the five digits.

53. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Tech Memo SEM-TM-63-3 November 1963	Helmet Visor Defog Capabilities and General Evaluation of the G-2C-1 Space Suit Assembly	Middleton, R.H., C.J. Muick, M. Alexander & F.K. Klemm

Abstract: The purpose of these evaluations is (1) to determine the capability of the Gemini prototype ventilation system to keep the helmet visor from fogging during various abort and/or emergency phases of the Gemini mission; (2) to determine what fogging solution will be adequate to prevent visor fogging in the event the ventilating system is inadequate during emergency orbital conditions; (3) to measure suit volume, body volume of the subject, and dead air space between suit and subject as a means of determining the efficiency of the ventilating system; and (4) to determine growth increments (ballooning) during the inflated state of the suit.

54. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TDR-63-36 May 1963 AD 410 451	Moments of Inertia and Centers of Gravity of the Living Human Body	Santschi, W.R., J. DuBois & C. Omoto

Abstract: A study was conducted to determine the moments of inertia and centers of gravity of a sample of 66 living male subjects representative of the Air Force population in stature and weight. Eight body positions were investigated: standing; standing, arms over head; spread eagle; sitting; sitting, forearms down; sitting, thighs elevated; mercury configuration; relax (weightless). The procedure was based upon the compound pendulum having a theoretical accuracy of approximately  $\pm 2$  to  $\pm 8$  percent depending upon position and axis. Orthogonal axes, defined as the intersections of the sagittal, frontal, and transverse planes through the standing body, were designated as X, Y, and Z. A set of 50 anthropometric dimensions was taken on each subject, as well as photographs of each subject in each position. Results of the study show that the average moment of inertia varied in this sample from 11 pounds in seconds<sup>2</sup> about the Z axis to 152 pounds in seconds<sup>2</sup> about the X axis. Linear regression analysis of moments of inertia versus stature and weight yielded correlation coefficients ranging between 0.77 and 0.98.

55. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TDR-63-55 June 1963 AD 411 556	Anthropometric Data In Three-Dimensional Form: Development and Fabrication of USAF Height-Weight Manikins	McConville, J.T., M. Alexander & S.M. Velsey

Abstract: This report describes the development of data and the sculpturing of manikins for use in designing Air Force protective garments and associated personal equipment, as part of a long-range program to present designers of

protective flight equipment with a variety of anthropometric data in three-dimensional form.

In part, the data are based on a reanalysis of the body statistics reported in WADC Technical Report 56-365, A Height-Weight Sizing System for Flight Clothing, with certain changes in the statistical rationale required by either functional or technical factors. The choice and application of the statistical data used are discussed in detail. Information is also given concerning the sculpturing techniques used in the fabrication of the body forms.

Supplementary anthropometric statistics describing the human body in a seated position are presented. These statistics are analyzed in accordance with the eight-size height-weight sizing system.

56. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TDR-63-123 December 1963 AD 600 618	Human Mechanics Four Monographs Abridged	Krogman, W.M. & G F.E. Johnston

Abstract: This report condenses the following four important monographs in the field of applied human mechanics:

1. Braune, W. and Fisher, O. Über den Schwerpunkt des menschlichen Körpers, mit Rücksicht auf die Ausrüstung des deutschen Infanteristen. (The Center of Gravity of the Human Body as Related to the Equipment of the German Infantry) Abh.d. math.-phys. cl.d. K. Sachs. Gesellsch. der Wiss., Bd. 26, S. 561-672. 1889. Copyright release obtained by permission from S. Herzel Verlag, Leipzig.
2. Fisher, O. Theoretische Grundlagen für eine Mechanik der Lebenden Körper mit Speziellen Anwendungen auf den Menschen, sowie auf einige Bewegungsvorgänge an Maschinen. (Theoretical Fundamentals for a Mechanics of Living Bodies, with Special Applications to Man, as well as to some Processes of Motion in Machines), B.G. Teubner, Leipzig and Berlin. 1906. Copyright release obtained by permission from B.G. Teubner, Leipzig.
3. Amar, J. The Human Motor: or The Scientific Foundations of Labor and Industry, E.P. Dutton Co., N.Y.; Geo. Routledge and Sons, Ltd., London. 1920. Copyright releases obtained from E.P. Dutton and Co., New York, and Routledge and Kegan Paul Ltd., London.
4. Dempster, W.T. Space Requirements of the Seated Operator. Geometrical, Kinematic, and Mechanical Aspects of the Body with Special Reference to the Limbs. WADC Technical Report 55-159, Wright Air Development Center, Air Research and Development Command, United States Air Force, Wright-Patterson Air Force Base, Ohio. 1955.

The first is a study of the main center of gravity in the human body and the center of several of its parts. It is based upon the measurement and



positional analysis of four frozen adult male cadavers, projected to an X, Y, Z coordinate system. The basic data are transferred to a living adult male soldier, with and without load, in differing military positions.

The second is the analysis of freely movable joint systems ("n-link systems") in the living human body. The aim is (1) to present the kinetics of joint systems, and (2) the analysis of states of motion and equilibrium. Part I presents a three-link joint system and the n-link plane and solid joint system. Part II is an application to the mechanics of the human body and to motion in machines (latter here omitted).

The third is devoted to the application of principles of mechanics to bodily movements, specifically oriented to work situations. There are discussions of musclebone kinetics in structure and function; the physiology of fatigue is stressed. Environmental factors are discussed: external, as climate, temperature, altitude, etc.; internal, as heart, lungs, nutrition, etc. Experimental devices to measure energy exchange are given. All data are finally interpreted in terms of actual work performance in tool use, time, and motion, etc.

The fourth is the analysis of the human body, utilizing osteological material, cadavers, and living subjects, in terms of body links and kinetics, differential tissue relationships, physique differences, and the range of normal variation, carried out for the purpose of more precisely defining the work space required by seated individuals in various tasks. The results include the presentation of these requirements for a variety of seated functional postures, as well as detailed plans for the construction of kinetically-correct two- and three-dimensional manikins.

57. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1963 AD 421 428	Anthropometric Survey of Turkey, Greece and Italy	Hertzberg, H.T.E., E. Churchill, C.W. Dupertuis, R.M. White & A. Damon

Source: Published by the MacMillan Company, New York, 1963.

Abstract: This report describes the planning and organization of the NATO Anthropometric Survey of 1960-61, and presents the tabulated data for 150 body dimensions taken on 3356 military personnel: 915 Turks, 1084 Greeks, and 1357 Italians. Besides body dimensions, the data gathered include photographs, skinfold thicknesses, and other measures on each subject permitting assessment of body composition. (Taken during the survey, but omitted from this volume, are data from X-ray photographs of the right hands of 150 Greek and 150 Italian subjects.) The tabulated data include the means, standard deviations, coefficients of variation of 150 body dimensions, as well as selected percentiles of each from the 1st to the 99th, for each total national sample and subsample. When available, USAF data are presented for comparison. Each dimensional listing is accompanied by a sketch locating the dimension, a

photograph illustrating the technique of measurement, and verbal instructions for procedure.

There are chapters, each signed by its own author, presenting team acknowledgements, an introduction to the problem, the technical procedures used, and a summary of the statistical methods employed. A preliminary somatotype study (based on every 10th man) describes the body types encountered, with illustrations of four physical types from each country and an analysis of skinfold-thickness data presents an estimate of body fat in the sample. A final chapter sketches the history of anthropometric surveys, and outlines the wider practical and scientific uses of anthropometric data. Appendices I and II present plans for the construction of special equipment, and Appendix III briefly outlines plans for future publications on these data.

58. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1963	Anthropometry	Damon, A., H.W. Stoudt & R.A. McFarland

Source: Human Engineering Guide to Equipment Design, Morgan et al., Editors, Chapter 11, McGraw-Hill Book Co., Inc., New York, Toronto, London, 1963.

Abstract: This 130-page chapter contains extensive anthropometric muscle-strength, and range-of-motion of body-segment data on numerous United States military populations. Their application to many types of human engineering problems is detailed.

59. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TDR-64-41 May 1964 AD 603 705	Finger Dexterity of the Pressure-Suited Subject	Walk, D.E.

Abstract: This study attempts to establish an objective baseline for evaluating the functional mobility of pressure gloves. The Purdue Pegboard Dexterity Test was employed to measure hand dexterity under three conditions: (1) subjects barehanded, but wearing an unpressurized A/P22S-2 full-pressure suit ensemble, (2) subjects gloved (HAK-3/P-22S-2) and suited, but not pressurized; and (3) subjects gloved, suited, and pressurized to 2.5 psi. The Purdue Pegboard Dexterity Test has been found to be a delicate indicator of hand dexterity in the test conditions. The test results show a marked reduction in dexterity even with the gloves and suit uninflated, and an additional loss when gloves and suit are inflated. The degree of loss of dexterity is believed to provide an objective measure whereby one operational aspect of pressure gloves may be evaluated.

60. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TDR-64-59 September 1964 AD 608 269	Reach Capability of the USAF Population. Phase I: The Outer Boundaries of Grasping-Reach Envelopes for the Shirt-Sleeved, Seated Operator	Kennedy, K.W.

Abstract: This report contains descriptions of the outer boundaries of the Minimum, 5th-, 50th-, and 95th-percentile grasping-reach envelopes of seated, shirt-sleeved operators. The two most important are the Minimum and 5th-percentile envelopes. These envelopes have been calculated to permit 99+ percent or 95 percent of the Air Force population, respectively, to reach any point at their boundaries. The report contains a critical resume of previous investigations of arm reach, and a description of the AMRL Grasping-Reach Measuring Device. The data-gathering and statistical procedures are included, and applications of the reach envelopes are discussed. Horizontal contours representing the outer boundary of the Minimum, 5th-, 50th-, and 95th-percentile grasping-reach envelopes are presented for each 5-inch level beginning at five inches below SRP (Seat Reference Point) and extending to 50 inches above SRP. The minimum envelopes extended from 2.5 inches below SRP to 48 inches above; the 5th-percentile envelope from four inches below SRP to 48.75 inches above. Horizontal distances from SRP to the boundary of each envelope are given at 15 degree intervals.

61. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TDR-64-66 July 1964 AD 606 039	Height-Weight Sizing of Protective Garments, Based on Japanese Air Self-Defense Force Pilot Data, with Fit- Test Results	Alexander, M., J.T. McConville, J.H. Kramer & E.A. Fritz

Abstract: This study discusses the development and test of a four-size Height-Weight sizing program of partial pressure and exposure suits designed for the Japanese Air Self-Defense Force. The sizing program is based upon an anthropometric survey of over 200 subjects, conducted at five air bases throughout Japan during the spring of 1961. The statistical rationale used in devising the Height-Weight program is presented along with the analysis of the anthropometric data. Two garments, the CSU-7/P Partial Pressure Assembly and the CWU-13/P Exposure Garment, were fabricated in accordance with the developed sizing program. A fit-test of these garments was conducted at Hamamatsu and Tachikawa Air Bases, Japan, in April 1963.

The results of the fit-tests served to validate the soundness of the basic survey data and subsequent development of the Height-Weight sizing program.



62. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-64-102 October 1964 AD 608 463	A Mathematical Model of the Human Body	Hanavan, E.P.

Abstract: A mathematical model for predicting the inertial properties of a human body in various positions has been developed. Twenty-five standard anthropometric dimensions are used in the model to predict an individual's center of gravity, moments and products of inertia, principal moments, and principal axes. The validity of the model was tested by comparing its predictions with experimental data from 66 subjects. The center of gravity was generally predicted within 0.7 inch and moments of inertia within 10 percent. The principal vertical axis was found to deviate from the longitudinal axis of the body by as much as 50 degrees, depending on the body position assumed. A generalized computer program to calculate the inertial properties of a subject in any body position is presented. The inertial properties of five composite subjects in each of 31 body positions is offered as a design guide. IBM 7094 digital computer programs are appended.

63. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-64-110 November 1964 AD 609 863	Moments of Inertia and Centers of Gravity of the Living Human Body Encumbered by a Full-Pressure Suit	DuBois, J., W.F. Santschi, D.M. Walton, C.O. Scott & F.W. Mazy

Abstract: The center of gravity and the moments of inertia of each of 19 male subjects, representative in stature and weight of the U.S. Air Force population, were determined. Two body positions: sitting and relaxed; and three modes of dress; nude, suited-unpressurized, and suited-pressurized, were investigated. The theoretical accuracy of the experimental procedures, based on a compound pendulum, ranged from 2 to 8 percent, depending on body position and axis. The moments of inertia were found to vary significantly between body positions and between nude and suited conditions. Correlation coefficients between the moments of inertia and stature and weight exceeded 0.9. Fifty anthropometric dimensions and frontal and profile photographs were obtained on each subject to serve as the basis for additional biodynamic analyses.

64. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-64-118 November 1964 AD 610 519	The Use of Lines of Nonextension to Improve Mobility in Full-Pressure Suits	Iberall, A.S.

Abstract: An important objective in the development of a full-pressure suit for a human being is to permit the wearer full mobility without interfering

with physical capability. Although the human skin is stretched during body motion, there is virtually no stretch along certain lines, here called "lines of nonextension." This investigation was undertaken to determine the efficacy of utilizing lines of nonextension to provide natural mobility and minimal ballooning in full-pressure suits. The program of investigation pursued was: (1) to map out these lines of nonextension, (2) to test whether string elements of high elastic modulus, a connected network, could be laid along these lines of nonextension without providing any constraint to mobility, (3) to obtain a highly mobile pressure-retaining layer to be constrained by the net, and (4) to construct and demonstrate an entire pressure-retaining garment system that makes use of necessary layers and string elements in a completely connected, netted covering for the body, with minimal constraint to mobility up to 5 psi. The technique, results, and collateral observations relevant to each of these phases are described. A mobile, pressure-retaining garment was developed by building each structural, functional layer into the composite garment in accordance with the basic design theory.

65. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-65-31 May 1966 AD 638 282	Relationships Between Flexibility, Anthropometry, and the Somatotype of College Men	Laubach, L.L. & J.T. McConville

Source: Research Quarterly, 37:2, 241-251, May 1966.

Abstract: Fourteen flexibility measurements, 63 direct and derived anthropometric measurements, and the somatotype of 63 college men, mean age of 19.0 years, were obtained in order to assess the relationships between flexibility and anthropometric measurements, anthropometric measurements and somatotype, and flexibility and somatotypes. The correlations between the flexibility measurements and the anthropometric measurements were low and mostly insignificant. Body fat, as measured by skinfold calipers, yielded fairly high significant negative correlations with the flexibility measurements. The correlations between the flexibility measurements and somatotype were insignificant. Generally high correlation coefficients were obtained between the anthropometric measurements and somatotypes.

66. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-65-73 December 1965 AD 632 241	The Anthropometry of Common Working Positions	Alexander, M. & C.E. Clauser

Abstract: Twenty-six dimensions of the human body in various working positions (standing, bending, kneeling, squatting, supine, and sitting) were obtained by photography or by direct measurement. The purpose of this study was to provide the human engineer with anthropometric data of various missile workers' positions so that more adequate work stations can be designed. Each

dimension is defined verbally and graphically; and the 5th, 25th, 50th, 75th, and 95th percentiles and other statistical data are presented.

67. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-65-74 March 1965 AD 462 062	Anthropometry of Japanese Pilot	Oshima, M., T. Fujimoto, T. Oguro, N. Tobimatsu, T. Mori, I. Tanaka, T. Watanabe & M. Alexander

Abstract: The results of an anthropometric survey of 239 pilots of the Japanese Air Self-Defense Force are presented. The survey took place in the spring of 1961 at five air bases located throughout Japan. Sixty-two body dimensions were measured on each subject by JASDF flight surgeons. Measurements of the head, face, trunk, arms, and legs were included for the purpose of sizing and designing pressure suits and associated protective gear for use in the F-104J weapon systems program. The percentiles, means, standard deviation, range, and coefficient of variation are presented for each body measurement. Comparisons with the 1950 USAF flying population are included. A detailed description is given for each measurement accompanied by explanatory diagrams. A four-size, Height-Weight program for JASDF pilots is presented for use by protective equipment designers.

68. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-65-107 October 1966 AD 674 306	Muscle Strength, Flexibility, and Body Size of Adult Males	Laubach, L.L. & J.T. McConville

Source: Research Quarterly, 37:3, 384-392, October 1966.

Abstract: Four measures of muscle strength, two measures of flexibility, 30 anthropometric measures (both direct and indirect), and the somatotypes of 45 male subjects were obtained and the interrelationships among these variables investigated.

A low but statistically significant correlation was found between hip-flexion strength and the range of motion of hip extension-flexion; however, this was the only strength measurement to correlate significantly with the flexibility measurements. Many statistically significant ( $p = .05$ ) correlations were found between the anthropometric and the strength measurements, but none between the anthropometric and the flexibility measurements. The only somatotype component to correlate significantly with the measures of muscle strength was mesomorphy; the correlations between the somatotype components and the measures of flexibility were insignificant.



69. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-163 December 1965 AD 630 639	Development of Design Standards for Ground Support Consoles	Kennedy, K.W. & C. Bates, Jr.

Abstract: Experience gained in using a single standardized ground-support console configuration in the WS 131B, Hound Dog, is discussed. Other ground console designs for possible standardization in future systems are described in detail. All designs are derived from a basic sit-stand configuration and will accommodate approximately 95 percent of the USAF male population and approximately 60 percent of the USAF female population. Each of the consoles can be made from five standard subassemblies. The suggested standard configurations permit engineering design freedom, yet restrict certain dimensional characteristics of the consoles to assure accommodation to the requirements and capabilities of the operator.

70. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-65-205 December 1965 AD 637 692	Procedure to Assess Energy Expended During a Short- Period Task	Walk, O.E. & E.H. Sasaki

Abstract: A procedure was developed to measure the energy expended in a rowing task completed during a 12-second zero-G parabola. The technique was based on completed expired air samples. The subject's expired air was collected under three conditions: (1) 30 seconds of rest, (2) 12 seconds of rowing, and (3) 15 seconds of recovery. The conditions were repeated ten times, and the subject's expired air was cumulated separately in three bags to obtain, in essence, a 5-minute collection for rest, a 2-minute collection for work, and a 2-1/2 minute collection for recovery. This procedure was replicated in four environments: laboratory, aircraft 1G level flights, aircraft 2G-1G-2G bank maneuvers, and aircraft 2G-0G-2G parabolic maneuvers. The results showed that the body reacted to a change in physical activity and returned to a state of equilibrium much more quickly than previously reported in the literature. The volumes of expired air, oxygen, and carbon dioxide in each condition (rest, work, and recovery) were similar in the four environments, but the specific effects, if any, of the differential gravity levels were negligible and unsystematic.

71. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-65-216 December 1965 AD 622 443	An Analysis of the Inertial Properties and Performance of the Astronaut Maneuvering System	Tieber, J.A. & R.W. Lindemuth

Abstract: The inertial properties and performance parameters of an Astronaut Maneuvering System (AMS) are determined by mathematical modeling. The inertial properties of an astronaut in a space suit are determined by

modification of an existing mathematical model of the human body to include a mathematical model of a space suit. The space suit model is based on measurements of suited subjects and suit weight regression equations. The inertial properties determined are: (1) location of the system center of mass, (2) moments and products of inertia about axes through the center of mass, (3) the principal moments of inertia, and (4) the orientation of the principal axes. These properties are used in a computer program developed to analyze the performance of the AMS by simulating the operation of the MMU in the system. Performance parameters determined are: linear and angular acceleration, velocity, displacement, and fuel consumption. Maneuver and propulsion efficiency factors are defined and calculated. The efficiency factors indicate loss of system efficiency due to inertial cross-coupling, misalignment of center of mass and thrust line, and intermittent thruster operation. The efficiency factors are used to compare system performance during various maneuvers.

72. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
May 1965	Motion Performance of Pressure-Suited Subjects Under Zero and Lunar Gravity Conditions	Simons, J.C., D.E. Walk & C.W. Sears

Source: Aerospace Medicine, 36:5.

Abstract: The motions of unsuited and pressure-suited subjects were studied as they performed lunging, egressing, and landing tasks during the weightless and lunar gravity maneuvers of a large cabin aircraft. Performance data are presented for various combinations of clothing, gravity, and body position conditions. Time and contact data are presented for the egress motion as it is influenced by changes in the exit diameter. Motions of suited subjects generally required 30 percent more time than corresponding motions of unsuited subjects under both gravity levels. Most motions required 35 percent more time during zero-G than during lunar-G. No significant differences in egress time were found for four body-position configurations. Five inches of exit clearance improved egress time by 6 percent. Accuracy of motion rather than time of motion appeared to be a more sensitive measure of operator performance for the egress task.

73. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-66-17 May 1966 AD 637 764	A Study of One-Handed Lifting	McConville, J.T. & H.T.E. Hertzberg

Abstract: This research is intended to assist in establishing realistic criteria for the size and weight of industrial packages. The problem of such criteria is discussed, numerous important objective and subjective factors that potentially affect human weightlifting ability are mentioned, the proper approach to the design of industrial loads is pointed out, and additional

programs of investigation that would clarify other aspects of the problem are outlined. This study examined the interaction of two variables: (1) the weight, and (2) the width of one-handed symmetrical boxes which a sample of 30 adult males were able to lift from the floor to a table 30 inches high. No carrying was involved in this study. The subject sample was chosen to be a reasonable representation by height and weight of the U.S. Air Force population. All lifts were made with the preferred hand under "ideal" laboratory conditions. The experimental variable, box width, was varied from 6 to 32 inches. The maximum weight of the box that subjects were able to lift varied linearly, but inversely, with the width of the box. From this sample, the maximum weight that 95 percent of the population would be able to lift--but not necessarily carry--can be expressed by a linear equation:

$$\text{Weight (pounds)} = 60 - \text{width (inches)}.$$

The numerical values of this formula provide a recommended upper limit on the design of industrial or military equipment which must be lifted under ideal conditions. If the expected conditions of use are less than ideal, or if carrying for appreciable distances is likely to be necessary, reasonable reductions in weight, or size, or both should be made by the manufacturer.

74. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-66-27 October 1966 AD 646 716	Aperture Sizes and Depths of Reach for One- and Two- Handed Tasks	Kennedy, K.W. & B.E. Filler

Abstract: This report presents data on (1) the optimal sizes and locations of maintenance apertures, and (2) man's working-reach distances through such apertures, for both the shirt-sleeved and the pressure-suited conditions. In all cases, the vertical dimension of the aperture permits the technicians to maintain simultaneous visual and manual contact with the task area. Data include Depth of Reach, Breadth of Aperture, Vertical Dimension of Aperture, and the distances from the floor from both the lower and the upper edges of these apertures. Different apertures provide for forward or lateral reaches, in the standing or seated position, with one or both arms.

Data are reported in percentiles, including the 5th, 25th, 50th, 75th, and 95th. Ranges, means, and standard deviations are given. Recommendations are made regarding the appropriate application of the data to the sizing and location of maintenance accesses.

75. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-66-185 December 1966 AD 656 311	Measurements of Muscle Strength	Laubach, L.L. & M. Alexander

Source: Integrated Life Support System Study (20-Day Evaluation Program), AMRL-TR-66-185, Metzger and Fritz, Section VIII, December 1966.



Abstract: The research described in this section was designed to determine the effect of long-term confinement on human muscle-strength capabilities. Twelve strength tests were administered to two of the participating subjects immediately prior to their entry, and upon their emergence from a 20-day confinement period in the Biological Testing Center.

76. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
November 1966	An "Anvil" for Sliding-Caliper Repair	Hertzberg, H.T.E.

Source: American Journal of Physical Anthropology, 25:3, 335-336, November 1966.

Abstract: This note presents working drawings and a photograph of a tool that facilitates immediate repair of sliding calipers damaged during anthropometric surveys.

77. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
April 1967	Maximal Static Force vs. Stress Measurements as Criteria for Establishing Optimal Work Conditions	Kroemer, K.H.E.

Source: Preprints of the Scientific Program of the Aerospace Medical Association, 166-167, April 1967.

Abstract: Differences between static and dynamic usage of muscles and ensuing consequences for arrangements of controls are discussed. Methods of assessment of physical stress of human operators are briefly reviewed.

In a series of experiments, eight male subjects operated cranks and levers (radii 15 and 30 cm) against torques of resistance of 2 to 6.8 m.kp. During trials of 10 minutes each, the subject performed either 100 or 200 to-and-fro movements, the angles of rotation being 90 or 180 degrees. The range of travel of the handles was adjusted to a variety of positions within the reach capabilities of the subjects. Experimental conditions judged by the subjects as most agreeable and which, at the same time caused least increases in their pulse rates, were considered to be optimal for the dynamic work performed.

The results obtained indicate that measurements of man's maximal static forces do not provide an adequate basis for the layout of controls which must enable human operators to perform dynamic-submaximal work with the least amount of fatigue and physical stress.

78. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-67-63 May 1967 AD 658 441	Two-Handed Retention on Various Handle Configurations	Garrett, J.W., M. Alexander & W.G. Bennett

Abstract: This report presents data on the manual grip-retention capability of seated persons. Nine male subjects, grasping experimental ejection actuators located forward of an ejection seat pan, were required to maintain their grasp against force loadings of 50 to 500 pounds. Grip retention at various increments of time to a maximum of 30 seconds is compared for each of the four handles: a T-bar, twin grips, a standard D-ring, and a flexible Gemini-type loop. Test results indicated that the T-bar provides the greatest grip-retention capability. Potential applications of these performance data are discussed.

79. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-67-82 May 1967 AD 751 734	Notes on Anthropometric Technique: Anthropometric Measurements--Right and Left Sides	Laubach, L.L. & J.T. McConville

Source: American Journal of Physical Anthropology, 26:3, 367-370, May 1967.

Abstract: In order to discover whether statistically significant differences exist between measurements taken on the right and left sides of the body, 21 such anthropometric dimensions were compared. In eight cases, significant differences were found. Six of these dealt with the forelimb, in which the dimension measured on the right side was greater. Since data on handedness are lacking, we do not know whether this is related to the handedness of the subjects.

80. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-67-135 June 1969 AD 716 632	Body Composition in Relation to Muscle Strength and Range of Joint Motion	Laubach, L.L.

Source: Journal of Sports Medicine and Physical Fitness, 9:2, 89-97, June 1969.

Abstract: The data on 27 body composition, anthropometric, and physical performance items were obtained from 45 male subjects and the interrelationships among these measures investigated.

Many statistically significant ( $p = .05$ ) zero-order correlations were found between the muscle strength and the body composition measures, but none between the range of joint motion measures and body composition. The somato-type components correlated much higher with measures of muscle strength when

Stature was partialled out of the correlation. The resulting correlations among the physical performance items and the body composition measures when body weight was held constant were generally lower than the same zero-order correlations and first-order partial correlations (stature held constant).

A few (six) significant correlations were found between the range of joint motion and body composition measurements when both stature and body weight were held constant. Multiple regression equations for the prediction of the physical performance items from the anthropometry and body composition measures are listed.

81. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-67-180 January 1968 AD 708 118	The Conference on Standardization of Anthropometric Techniques and Terminology	Hertzberg, H.T.E.

Source: American Journal of Physical Anthropology, 28:1-16, January 1968.

Abstract: The conference, attended by anthropologists, engineers, dental and medical researchers, physical educationists, and statisticians, took place on 28-30 March 1967 in the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. The ultimate purpose was to improve the comparability of anthropometric data from all workers, by establishing standards for the many new dimensions required in engineering anthropology, and by developing a terminology that reconciles the new standards with previous usages. In this effort, the group selected a list of dimensions (though with dissent on type and number) recommended as a minimum for all human biological surveys; and they chose from previous usage a terminological structure whose form, content, and mode of presentation they recommend as standard practice by all anthropometrists. Both official and dissenting lists are presented, and the terminological structure is described, with examples.

Despite solid progress toward a standardized technology encompassing both classified and modern practices, the conference left numerous points of technique or terminology unsettled, some of which are briefly described. Hence, future meetings appear necessary, perhaps annually, until such remaining problems can be resolved.

82. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-67-203 January 1968 AD 670 869	Anthropometry of the Human Ear (A Photogrammetric Study of USAF Flight Personnel)	Alexander, M. & L.L. Laubach

Abstract: A technique was developed which enables precisely specified ear dimensions to be measured directly from PhotoMetric slides. Summary statistics for each of the various ear dimensions are presented for a sample of 500 subjects randomly chosen from a total series of 2236 photographic slides collected during the 1957 Anthropometric Survey of USAF male flying



personnel. Regression equations for predicting the various Tragus Radii angular measurements of Ear Length and Ear Breadth are presented. The reliability and objectivity of the technique are discussed. A complete inter-correlation matrix for all variables studied in this research is also shown.

83. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-67-217 August 1971 AD 731 183	An Introduction to Relaxed Hand Anthropometry	Garrett, J.W.

Abstract: Anthropometric data comparing the length of the relaxed hand with the flat, straightened hand are presented. The correlation coefficient between the hand length in the two positions is not high. A forthcoming comprehensive research program on the anthropometry of the hand is revealed.

84. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-68-1 March 1971 LC No. 74-74-607818 AD 723 629 (Volume I) AD 723 630 (Volume II)	A Collation of Anthropometry	Garrett, J.W. & K.W. Kennedy

Abstract: Scientists and engineers are faced with the responsibility of comparing anthropometric data from different populations. So far, the labors required to find and identify comparable dimensions have been left to the individual researcher. To relieve him of the burden of this effort, the descriptions of approximately 2000 anthropometric dimensions from 47 sources have been collated and reported in a manner that makes comparisons convenient. Thirty-nine of these sources are primary sources of statistical data. Thirty-six of the latter were published since 1940, and three are soon to be published. Several classic sources of anthropometric technique have also been collated.

85. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-68-24 August 1968 AD 681 457	Clearance and Performance Values for the Bare-Handed and Pressure-Gloved Operator	Garrett, J.W.

Abstract: This study provides the design engineer with clearance and performance values for operators wearing the A/P22S-2 pressure glove. Thirty-six anthropometric and biomechanical measures on the nude hand, gloved and unpressurized, and gloved and pressurized, were taken. The data for each measure on 27 subjects are both summarized for all subjects and reported independently by

glove size worn. Possible uses for each of the measures are suggested and specific design factors for these uses are recommended.

86. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-68-61 December 1968 AD 695 470	Ultrasonic Determination of Body Composition	Stouffer, J.R.

Abstract: The objective of this study was to determine the feasibility of using ultrasonic techniques to determine the volume of fat, muscle, and bone tissue of the living body. Ultrasonic equipment, including a mechanical scanning and recording device, was used to produce cross-sectional maps of a live anesthetized hog, three fresh hams, and three human subjects (endomorph, mesomorph, and ectomorph). Thirteen 360-degree cross-sectional scans on the live hog demonstrated the feasibility of using the technique on live animals. Cross sections of the three hams demonstrated the accuracy of estimating the areas of volumes of the three tissue components from ultrasonic scans. The ultrasonic mapping of the human subjects demonstrated that the technique could be used on all parts of the human body and, in addition, provided an indication of the range of values of individuals of diverse body types.

87. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-68-80 July 1968 AD 848 621	Ergonomics in the Design of Office Furniture: A Review of European Literature	Kroemer, K.H.E. & J.C. Robinette

Abstract: This report discusses the European literature on "health" sitting postures and, relatedly, of suitable office and shop furniture, especially of chairs. Recommendations of orthopedists, physiologists, and physical anthropologists are summarized and tabulated for the height, shape, and dimensions of the seat surface; for the shape and dimensions of the back rest; and for the height of office desks, as well as for tables and stands to be used with office machines, such as typewriters.

88. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-68-113 December 1968 AD 737 412	World Diversity in Human Body Size and Its Meaning in American Aid Programs	Hertzberg, H.T.E.

Source: OAR Research Review, 7:12, December 1968.

Abstract: This brief review shows quite conclusively that our Air Force people (and hence, our population at large) are giants as compared to these other populations. Not only is the large majority of the flying personnel

among our Mediterranean and Oriental allies below our 50th percentile in most dimensions, showing that their sizes are different from ours, but also their proportions are different. Hence, smaller sizes of garments which fit us will not necessarily fit all of the them adequately. In any case, it is inescapable that reliable anthropometric data on such populations are essential to the effective solution of the vexing and expensive fitting problems associated with clothing and equipment furnished our allies under our aid programs.

89. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-68-143 August 1969 AD 695 040	Push Forces Exerted in Sixty-Five Common Working Positions	Kroemer, K.H.E.

Abstract: Experiments were conducted to measure the maximum isometric horizontal push forces exerable in 65 common working positions. The subjects (45 male college students), while pushing horizontally, either anchored their feet against a footrest or braced themselves against a vertical wall. Means, standard deviations, and 5th percentiles of the forces exerted are reported.

Male operators can exert horizontal static forces of at least 25 kp (55 pounds) pushing with one hand, at least 50 kp (110 pounds) pushing either with both hands or with the shoulder, and at least 75 kp (165 pounds) pushing with back--provided they anchor their feet or, better, brace themselves against a vertical wall. A vertical push-panel that allows most subjects to exert maximum horizontal force has a rough surface, is 40 cm (16 inches) wide, and extends from 50 cm (20 inches) above the floor to 125 cm (50 inches) above the floor.

90. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-68-144 May 1970 AD 708 741	Problems in Assessing Muscle Strength	Kroemer, K.H.E. & J.M. Howard

Abstract: Muscle strength is typically reported in terms of "maximum." Experimental data illustrate the importance of defining the method of force exertion and of performance evaluation. Contracting the muscles in different ways or selecting different indexes from the same performance record can result in distinct "maximum" strength scores. To facilitate standardization of experimental procedures and comparison of strength data, a checklist is proposed.

91. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-68-151 December 1970 AD 725 386	A Computer Program for Calculating Parnell's Anthropometric Phenotype	Laubach, L.L. & M.E. Marshall



Source: The Journal of Sports Medicine and Physical Fitness, 10:4, 217-224, December 1970.

Abstract: A specific computer program was written and compiled for the calculation of Parnell's anthropometric phenotype. This computer program is illustrated and discussed. A total of 2420 male subjects from the 1967 U.S. Air Force Anthropometric Survey were phenotyped in this manner. Descriptive statistics for the phenotype distributions are given for the entire sample divided into 5-year age categories.

92. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-68-164 March 1970	Ground Areas Visible from the Aircraft Cockpit Eye Position: A Method of Evaluation	Kennedy, K.W.

Source: Problems of the Cockpit Environment, AGARD Conference Proceedings No. 55, Amsterdam, Netherlands, March 1970.

Abstract: The purpose of this research is to develop a realistic and objective method for comparing aircraft in terms of the ground areas visible from their cockpits. The method consists of calculating the area of the earth's surface visible from the pilot's eye position, within a radius of 3,000 feet and of 18,000 feet. The ground area visible, expressed as a percentage, may be regarded as an index of the visibility from the cockpit. A camera, which produces superimposed pictures from two lenses separated by the average interpupillary distance, is located at the cockpit-design eye position, and the photograph obtained shows a panorama of what the pilot could see if he rotated his head from side to side. To illustrate that only part of the terrain beneath the aircraft is visible from the design-eye position, angular coordinates describing the outlines of obstacles to vision are projected to the ground. Through simple trigonometric analysis, the location of the points where these vectors "strike" the ground are calculated relative to ground "0," a point on the ground directly below the aircraft. Once all necessary points are determined and plotted, it is possible to define the areas on the surface of the earth that are visually inaccessible from the cockpit-design eye position.

93. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-6 August 1969 AD 697 022	Anthropometric Dimensions of Air Force Pressure-Suited Personnel for Workspace and Design Criteria	Alexander, M., J.W. Garrett & M.P. Flannery

Abstract: The results of an anthropometric survey of USAF personnel wearing the A/P22S-2 Full Pressure Suit fitted in accordance with the USAF Eight-Size, Height-Weight Sizing Program are presented. One hundred and thirty-eight measures were taken on each of 34 subjects standing, sitting, and supine, with

the suit in the uninflated, inflated, and inflated-restrained conditions. Forty circumferences were measured on a separate sample of 32 subjects standing and sitting, with the suit uninflated and inflated. Pictorial and verbal descriptions of the dimensions and detailed numerical results, including clearance ranges, are presented. Graphs comparing various dimensions across suit sizes are presented in the Appendix.

94. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-9 1970 AD 710 593	Human Strength: Terminology Measurement and Interpretation of Data	Kroemer, K.H.E.

Source: Human Factors, 12:3, 297-313, 1970.

Abstract: Application of strength data to human engineering problems is often hampered by ambiguities of both terminology and data. This paper attempts to point out some of the problems. After defining "strength" and clarifying related terms, mechanical, physiological, and statistical implications of strength testing are discussed. It becomes obvious that strength data are fully relevant to human engineering problems only if the operator must exert maximal static muscle force; if submaximal forces are required, the applicability of strength data is very limited. Research is needed to establish relations between human static force capacity and the abilities to perform maximal or submaximal dynamic work. At present, there is little evidence that static force data accurately predict dynamic performance.

95. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-26 March 1970 AD 710 202	Anthropometry of the Air Force Female Hand	Garrett, J.W.

Abstract: This report contains descriptions of 56 anthropometric dimensions measured on the hands of 211 Air Force female personnel (WAF, Nurse Corps, and Biomedical Sciences Corps), aged 18-56. Summary statistics including the means, standard deviations, ranges, selected percentiles, measures of distribution, and coefficients of variation are presented for the 56 dimensions. Also included are statistical variations by age, rank, and Corps, within the sample; a complete correlation matrix; bivariate tables; and nomographs for various selected combinations of dimensions.

96. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-42 March 1970 AO 709 883	Anthropometry of the Hands of Male Air Force Flight Personnel	Garrett, J.W.

Abstract: This report contains descriptions of and data on 56 anthropometric dimensions of the hands of 148 male Air Force flight personnel. Selected dimensional comparisons indicate that this sample is representative of the total group of Air Force flight personnel. Summary statistics presented include the means, standard deviations, ranges, selected percentiles, and coefficients of variation. Also included are data on the age, rank, major Air Command, and commissioned status of the sample; a complete matrix of intercorrelations among the anthropometric dimensions; bivariate tables; multiple regression equations; and nomographs for selected combinations of dimensions. A tariff for the U.S. Air Force 12-size glove program revised to reflect the latest anthropometric data is presented in the appendix.

97. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-57 February 1970 AD 707 142	Foot Operation of Controls: Speed of Activation and Exertion of Force to Pedals; Perception, Speed and Accuracy of Leg and Foot Motions	Kroemer, K.H.E.

Source: Ergonomics, 14:3, 333-361, 1971.

Abstract: The literature pertaining to foot operation of controls is reviewed and a new experiment reported.

Published experimental results clarify only some isolated aspects of leg and foot motions. Even the relatively often investigated speed of operating pedals and forces that can be applied to them were studied under such different experimental conditions that no general statements are possible concerning what pedal can be operated most quickly or forcibly. Opinions about the advantages and disadvantages of hand versus foot operation seem not generally based on experimental findings.

In an experiment, 20 seated young adult male subjects moved their right foot as rapidly as possible over distances of 15 cm to circular targets. The direction of these discrete movements had no appreciable effect on the accuracy of motion. Forward motions of the vertical or almost vertical lower leg were slightly faster than backward or lateral motions of the elevated lower leg. All motions could be performed in about 0.1 second.

98. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-61 February 1970 AD 706 411	The Anthropology of Anthropomorphic Dummies	Hertzberg, H.T.E.

Source: Proceedings of the Thirteenth Stapp Car Crash Conference, No. 690805, pp. 201-214, Boston, Massachusetts, December 1969.



Abstract: This paper describes anthropological aspects of a cooperative program to create a "family" of anthropomorphic dummies representative of the American population. The dummies are for use in crash-tests to improve public safety in motor vehicles. The anthropomorphic dummy is that type which closely approximates a given percentile level of the human body in size, form, segment mobility, total weight, segment weight, weight distribution, and resiliency of its "flesh" covering, and is usually able to withstand 100 G. The history of this development is briefly sketched from its beginning in 1949. In the current program, the best available data have been chosen for three adult sizes: the 95th- and 50th-percentile males, and the 5th-percentile female. The body-forms being sculptured will provide a set of national standards for size, shape, and weight. Future phases will involve the development of dummy organ-masses approximating the sizes and vibratory responses of those in the living torso. Deficiencies of the anatomical, anthropometric, biomechanical, and physiological data used for these body-forms are noted; and suggestions are made for improvement, so that future dummies may be made more reliably representative of the using population.

99. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-70 August 1969 N70-29085 AD 710 622	Weight, Volume, and Center of Mass of Segments of the Human Body	Clauser, C.E., J.T. McConville & J.W. Young

Abstract: This study was designed to supplement existing knowledge of the weight, volume, and center of mass of segments of the human body and to permit their more accurate estimation on the living from anthropometric measurements. Weight, volume, and center of mass of 14 segments of the body were determined on 13 male cadavers. Presented are descriptive statistics of these variables as well as a series of regression equations predicting these parameters from anthropometry. Included in the seven supporting appendices are reports of studies of the mid-volume of segments as an approximation of their center of mass, relationships between standing and supine anthropometry and postmortem changes in gross body size, and comparisons between densities of fresh and preserved human tissues.

100. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-107 December 1969 AD 705 450	The Relationship of Strength to Body Size and Typology	Laubach, L.L. & J.T. McConville

Source: Medicine and Science in Sports, 1:4, December 1969.

Abstract: Thirteen measures of static strength, 13 body-size measurements, and the somatotypes of 77 male subjects were obtained and the interrelationships among these measures were investigated. Summary descriptive statistics are given for the 29 variables studied. Simple and selected

partial correlations were calculated and the results interpreted at the 0.05 level of significance.

The zero-order correlations revealed that body weight, lean-body mass, and mesomorphy yielded the highest correlations with mean total strength. Stature, skinfold measurements, and the length of the lower arms of the body were not related to mean total strength; however, the relationship between the strength and length of specific torso and arm linkages while weak is definitely indicated. The first-order partial correlations (weight held constant) between body-size measures, lean-body mass, and strength measures were about the same as the identical zero-order correlations; however, with weight held constant the skinfold measurements yielded many significant correlations with muscle strength. By holding the effects of stature constant, the somatotype components produced several significant correlations with the static-strength measures. The second-order partial correlations (weight and stature held constant) revealed that the subscapular and suprailiac skinfolds are more of a factor in the exertion of static strength than the triceps skinfold.

It would appear that the measures of body size, typology, and composition used in this analysis were not effective predictors of muscle strength as measured by the static-contraction method.

101. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-122 April 1971 AD 724 061	The Adult Human Hand: Some Anthropometric and Biomechanical Considerations	Garrett, J.W.

Source: Human Factors, 13:2, 117-131, 1971.

Abstract: Recent studies of the anthropometry and selected biomechanical characteristics of hands are summarized. These include: (1) conventional anthropometry of male and female hands, (2) the anthropometry of the relaxed hand, (3) comparison of certain engineering anthropometric and performance parameters between bare and pressure-gloved hands, and (4) the ability to retain grips on selected handles under high dynamic loads. The utility of these data for human factors engineering is discussed.

102. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-123 October 1970 AD 880 934	Visibility Toward the Ground from Selected Tactical Aircraft	Kennedy, K.W. & D. McKechnie

Abstract: A method of evaluating vision toward the ground from the cockpit eye position is presented and demonstrated on selected aircraft. Consideration is given to the level aircraft attitude for the following cockpits: A-1E Pilot, A-1E Copilot, A7A, A-26A Pilot, A-26A Copilot, C-123B Copilot, F-5A, F-5B Front, F-5B Rear, F-105D, F-11A Pilot, O-1A Pilot, O-2 Pilot, OV-10A Pilot, and RF-4C Front; and to selected attitudes of pitch and roll for the

RF-4C Front. Vision toward sectors of terrain, defined in terms of ground radii, slant ranges, and position relative to the aircraft, is expressed as a percent of the total within the sector. These percentages are valid for any altitude since ground radii and slant ranges are expressed as multiples of altitude.

103. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-127 October/November 1969 AD 697 455	"Zoom Bag Scenario"	Garrett, J.W. & M. Alexander

Source: Interceptor, 11:10-11, pp. 20-21, October-November, 1969.

Abstract: This article presents the background information concerning the joint efforts of the Anthropology Branch and Pressure Suit Depot, Tyndall Air Force Base, Florida, in conducting anthropological research involving pressure-suited flight personnel.

104. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-69-141 February 1972 AD 740 259	Human Engineering the Keyboard	Kroemer, K.H.E.

Abstract: The standard typewriter keyboard serves as a model for keyboards of teletype writers, desk calculators, consoles, computer keysets, cash registers, etc. This man-machine interface should be designed to allow high-frequency, error-free operation with the least possible strain on the operator. This paper discusses several feasible, biomechanical improvements of the keyboard. Some experimental findings are described which support the use of the following design concepts: (a) the keys should be arranged in a "hand-configured" grouping to simplify the motion patterns of the fingers; (b) the keyboard sections allotted to each hand should be physically separated to facilitate the positioning of the fingers, and (c) the keyboard sections allotted to each hand should be declined laterally to reduce postural muscular strain of the operator.

105. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-3 March 1970 AD 706 888	Anthropological Applications in High Altitude Flight Systems	Alexander, M., J.W. Garrett & J.C. Robinette

Abstract: Anthropologists can provide data describing the human body as comprehensively as necessary, whether as naked flesh or encumbered with protective equipment from head to toe. This article reflects only some of the



research programs pursued in the Anthropology Branch on various phases of the dimensional requirements of the pressure suited man in the man-machine system. The spatial requirements for the man in a cockpit or capsule and on ejection and escape mechanisms or wearing clothing as protection against hostile environmental factors, such as heat, cold vacuum, high G, and radiation, present separate problems for the design engineer that can be helped effectively with the applicable anthropological data.

106. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-5 April 1972 LC No. 72-6000027 AD 743 113	Anthropometry of Air Force Women	Clauser, C.E., P.E. Tucker, J.T. McConville, E. Churchill, L.L. Laubach & J.A. Reardon

Abstract: This report describes and summarizes the results of an anthropometric survey of U.S. Air Force women carried out during 1968. Included in the report are a description of the methods and techniques used in the survey, descriptions--visual as well as verbal--of the measuring techniques used, and both uni- and bi-variate statistical summaries.

A total of 137 anthropometric dimensions was measured on a sample of 1,905 U.S. Air Force women: 548 officers or officer trainees and 1,357 enlisted women. This anthropometry included five measures of weight and fat thickness, 30 measures of body height and length, 26 measures of body girths, 15 measures of body breadths and depths, and 12 measures of body surface distance. There were, in addition, 30 measures of the head and face, three of the hand, and two of the feet. Thirteen measurements were remeasures of the subject while she was wearing a foundation garment. Background data gathered included age, rank, military occupation, birthplace, blood type, and age at menarche.

Part A describes the survey and the sample, illustrates the measuring techniques, and provides summary statistics including the mean, standard deviation, coefficient of variation, selected percentiles, measures of skewness and kurtosis, and frequency distribution for each measured variable. A study of the body density of a subsample of 95 women is also included.

Part B provides a variety of correlation and regression equation material, including the complete correlation matrix for age, the basic 124 measurements, grip strength, regression equations for all pairs of variables with at least moderately high intercorrelations, selected partial and multiple correlations, and a series of step-wise regression equations.

Part C consists of a set of approximately 400 bivariate frequency tables, plus one trivariate table.

Part D contains abbreviated statistical summaries for a set of indices, a group of computer variables, and the original measurement data separately for the officers and the enlisted women.

107. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-11 1970 SME Report AD 70-138 AD 739 170	Industrial Seating	Kroemer, K.H.E.

Abstract: Sitting as a working position is less fatiguing than standing, and can, therefore, be maintained longer. It is also a more stable posture and allows better controlled motions. The sitting posture should be upright, but relaxed, without excessive curvatures of the spinal column, and with the thighs about horizontal. The seated person must be free to choose and change his posture; no specific postures should be forced upon him. There are many interactions among work station design, body posture of the worker, and task performance. Based on anthropometric and biomechanical data, design aspects of work seats as well as of foot rests, office equipment, consoles, work benches, machine stands, and the like are discussed. Recommended dimensions for such work stations are presented.

108. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-25 July/August 1970 AD 727 259	Misconceptions Regarding the Design and Use of Anthropometric Dummies	Hertzberg, H.T.E.

Source: Motor Industry Research Association Bulletin, No. 4, 17-21, Lindley, Warwickshire, England, July/August 1970.

Abstract: This paper is a critique of a British article, "Anthropometric Dummies for Crash Research," by Searle and Haslegrave (Bulletin 5, Motor Industry Research Association, 1969), who sharply criticize an American commercial crash-test dummy. That paper, written by engineers, contains a variety of misconceptions regarding human biology and its influence on the design of crash-test dummies as well as on the choice of data for their construction. Because these views were widely disseminated in England, it was considered necessary to rebut them by tested principles and data for the benefit of human factors science.

109. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
ASD-TR-70-25 December 1970 AD 880 672	Cockpit Compatibility Studies Conducted with Aircrewmembers Wearing High Altitude Flying Outfits in B-57D, R-57F, F-104B, and F-106B Aircraft	Middleton, R.H., M. Alexander & K.W. Gillespie

Abstract: This report presents anthropometric measurements of the aircrewmembers, dimensions of the aircrewmembers while wearing the High Altitude Flying Outfit (HAFO) in the uninflated and inflated state, and measurements of the clearance between the aircraft cockpit canopy sills and the aircrewmembers seated in the

ejection seat when the seat is in the bottom, neutral, and fully raised positions. All aircrewmembers were measured in accordance with WADC TR 56-365, A Height-Weight Sizing System for Flight Clothing. The aircrewmembers were clothed (fitted) according to these measurements.

The dimensions of the aircrewmembers in the HAFO and the dimensions of the aircraft cockpit canopy sills and ejection seat were evaluated with regard to compatibility and crewmember mobility, visibility, and ability to carry out emergency escape procedures and normal aircraft control operations. It was within these areas that tests and evaluations were conducted, with the results noting those conditions which were unsatisfactory or would degrade the operational capabilities of the aircrewmember to function under normal and emergency conditions.

The outfits and aircraft references in this report were compatible with the outfits uninflated; however, with the outfits inflated, some difficulty was experienced.

110. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-33 September 1970 AD 715 975	Placement of Aircraft Controls	Garrett, J.W., M. Alexander & C.W. Matthews

Abstract: Data are presented to guide the designer in placing aircraft controls to be operated by lightly clothed or pressure-suited aircrewmembers. The capabilities of 17 subjects wearing various combinations of personal equipment to reach 81 locations with a 180 degree arc forward of Seat Reference Point were determined. Each subject was tested while wearing personal equipment, consisting of an underarm life preserver, parachute harness and, successively, a K2B flight coverall, an uninflated, and an inflated A/P22S-2 Full-Pressure Suit. The subjects sat in a seat configured to approximate Air Force specifications. During the tests they were restrained in the seat by a lap belt and shoulder straps with the inertial reel locked and again with the inertial reel unlocked. Pictorial descriptions of the dimensions, the reach capabilities of each subject, and recommended design values are presented.

111. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-34 May 1970 AD 717 793	Hand-Held Device to Measure Finger (Thumb) Strength	Kroemer, K.H.E. & E.M. Gienapp

Source: Journal of Applied Physiology, 29:4, 526-527, October 1970.

Abstract: A device that measures the force exerted by the thumb, or fingers, is described. This device is hand-held, easily calibrated, and is adjustable to various hand sizes and digit positions. Thumb strength data from 31 male subjects are reported.



112. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-58 September 1970 AD 727 258	"Average" Man is a Fiction: Range of Sizes is Key to Efficient Work Places	Hertzberg, H.T.E.

Source: Contract, 86-89, as part of the Symposium, "Ergonomics, Man's Newest Environmental Science," September 1970.

Abstract: This paper briefly defines the multidisciplinary field variously termed "Ergonomics" (in Europe), and "Human Factors," "Human Engineering," or "Human Factors Engineering" (in the United States), and outlines the part played therein by the subfield of Engineering Anthropology. This subfield's basic subdivisions of anthropometry, workplace design, biomechanics, and studies of human discomfort (due to tissue compression) are briefly described; and some principles of use of such data are illustrated by examples from U.S. Air Force experience. Some significant studies on work seats concerning the determination of discomfort and its amelioration are outlined, and the importance of data regarding body size and seating discomfort for furniture design is emphasized, especially for work seats and desks. In this connection, recent increases in body size in the American population are noted, and the sources of such data are named. A selected list of 35 references is appended.

113. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-75 October 1971 AD 733 551	Foot Forces Exerted at Various Aircraft Brake- Pedal Angles	Hertzberg, H.T.E. & F.E. Burke

Source: Human Factors, 13:5, 445-456, 1971.

Abstract: This study reports the forces (means and standard deviations) exerted by the foot at various angles of extension about its ankle. A sample of 100 rated pilots was used.

The forces were measured in a cockpit mock-up constructed around a specially instrumented F-80 rudder-pedal assembly. The right rudder pedal (hinged on the rudder bar) could be rigidly set to any desired angle between vertical and 75 degrees forward of vertical. Foot forces were measured at 11 positions of the instrumented brake pedal, for both neutral and extended positions of the right leg, and in three cockpit sizes (37 inch, 39-1/4 inch, and 41 inch)--66 measures on each man. In all three conditions, maximal forces were exerted with a 20 degree zone between about 15 degrees and 35 degrees forward of vertical. Subjective comfort preferences, expressed by 86 pilots, closely paralleled the force findings. It is concluded that aircraft brake-pedal systems should be designed to maximize the effectiveness of the foot in that optimal zone, and that the same zone should be considered for other foot-operated controls, like automobile accelerator pedals.

114. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-114 January 1971 AD 720 252	Horizontal Static Forces Exerted by Men Standing in Common Working Positions on Surfaces of Various Traction	Kroemer, K.H.E. & D.E. Robinson

Abstract: Experiments were conducted to measure maximal isometric horizontal push forces. Twenty-eight male subjects pushed forward with both hands, laterally with the preferred shoulder, and with their backs. Reaction force for body stabilization was provided by a vertical wall, a foot rest, or by floor-shoe combinations with coefficients of static friction of approximately 1.0, 0.6, and 0.3. Means, standard deviations, and 5th percentiles of the exerted forces are reported. In comparing the experimental data with results previously published, it is concluded that body weight cannot serve as a reliable predictor for push force capability from floors of various tractions. Estimates for static horizontal push as well as pull force capabilities of one or several men are tabulated in relation to traction available to the operator. An appendix contains coefficients of static friction between nineteen floor materials and eight shoe materials.

115. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-70-124 March 1970 AD 724 506	Towards Standardization of Muscle Strength Testing	Kroemer, K.H.E. & J.M. Howard

Abstract: Male subjects ( $n = 24$ ) exerted maximal horizontal forces either trying to maintain a constant level over 5 seconds, or increasing steadily to the subjective maximum, or in vigorous jerks of the body. Statistical analysis ( $p < 0.01$ ) indicated that these different techniques of force generation can result in different peak impulses. For the force maintained over 5 seconds, different scores (peak, and 12 averages during the exertion period) were extracted from the recorded force curves. Many of the resulting scores were significantly different from the others. Thus, a number of distinctly different "strength" scores resulted either from different techniques of force generation used by the subjects, or from different statistical treatments of the same raw data by the experimenter.

To standardize measures of "strength," a definition of strength, a checklist to control experimental techniques, and a regimen to calculate the strength index are proposed.

116. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-71-52 1971 AD 736 108	Seating in Plant and Office	Kroemer, K.H.E.

Source: American Industrial Hygiene Association Journal, 32:10, 633-652, 1971.

Abstract: Sitting as a working position is less fatiguing than standing and can, therefore, be maintained longer. It is also a more stable posture and allows better control of motions. Based on anthropometric and biomechanical data, design aspects of work seats as well as of foot rests, office equipment, consoles, work benches, machine stands, and the like are discussed. Recommended dimensions for such work stations are presented.

117. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-71-88 August 1972 AD 754 924	Link System of the Human Torso	Snyder, R.G., D.B. Chaffin, & R.K. Schutz

Abstract: The objective of this study has been to develop a quantitative description of the mobility of the human torso. This has been accomplished by a systematic multidisciplinary investigation involving techniques of cadaver dissection, anthropometry, radiography and cinefluoroscopy, photogrammetric, and computer analysis. Seventy-two anthropometric dimensions were obtained on 28 male volunteers, including bone lengths of the extremities and vertebral landmarks. These subjects were statistically matched for both stature and weight to a 1967 USAF anthropometric survey of 2385 adult males. Both radiographs and photographs from different viewing angles were then taken of the subjects while they performed specific reach motions. Statistical regressions were obtained which describe how specific surface markers and bone reference points move in relation to the elbow position for both seated and standing subjects. The major results of the study are: (1) prediction equations and graphs depicting both surface marker and bone reference point locations for a large range of body positions and specific anthropometric variables, (2) prediction equations and graphs describing how the base of the spine reference point (fifth lumbar spinal surface marker) moves in relation to defined seated and standing reference points for given reaches, and (3) a statistical tabulation with illustrations of 72 anthropometric dimensions. It was found that the surface landmarks selected could predict precise locations of the underlying anatomical landmarks. Both the prediction equations and graphical results allow the construction of alternative linkage systems of the human torso for design purposes.

118. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-71-102 January 1972 SAE Paper No. 720004 AD 735 315	Pedal Operation by the Seated Operator	Kroemer, K.H.E.

Source: Presented at the Society of Automotive Engineers (SAE), Automotive Engineering Congress, Detroit, Michigan, January 1972.



Abstract: This paper attempts to serve three purposes: (1) summarize the open scientific literature on muscular force applicable to pedals, and on the efficiency of foot motions on or between pedals, depending on the body support and the body posture of the seated operator; (2) discuss the applicability of such studies in automobile (or other equipment) design, especially to the design, selection, and arrangement of foot-operated controls; and (3) point out that for most conventional vehicles and equipment, modes of seating and of pedal arrangement and operation follow largely common experience and tradition, and only partly scientific findings. For new man-machine systems, new solutions seem possible.

119. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-71-107 January 1972 SAE Paper No. 720005 AD 735 316	The Human Buttocks in Sitting: Pressures, Patterns, and Palliatives	Hertzberg, H.T.E.

Source: Presented at the Society of Automotive Engineers (SAE), Automotive Engineering Congress, Detroit, Michigan, January 1972.

Abstract: After a brief description of relevant buttock structure, the author presents summary data on buttock size, tuberosity locations, and other dimensions needed for improved seat design, as measured from a sample of 35 young males chosen to approximate the range of USAF flying personnel.

Summary load patterns for two angles of seat back (pelvic inclination) are shown, and suggestions to reduce the discomfort of long-continued sitting are made. Curves and data for successful USAF seat surfaces are presented. Citing recent increases in American body size, the author calls for an anthropometric survey on a national sample in which numerous data needed for automotive and other industrial design would be acquired.

120. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-71-119 February 1972 AD 740 930	Human Force Exertions in Aircraft Control Locations	Thordsen, M.L., K.H.E. Kroemer & L.L. Laubach

Abstract: Experiments were conducted to measure the maximum isometric forces which male subjects could exert at six locations of hand operated aircraft controls. Forces were measured in two vertical and four to eight horizontal directions. The subjects (n = 51) sat in a simulated aircraft seat and exerted forces on a cylindrical handle. Selected anthropometric dimensions were obtained on the subjects and compared with those from the 1967 USAF anthropometric survey of flying personnel. Summary statistics including the mean, standard error of the mean, standard deviation, standard error of the standard deviation, coefficient of variation, symmetry, kurtosis, and selected percentiles are presented for each of the 44 force exertion measures. An analysis of the magnitude and direction of the force components, recorded in a

plane orthogonal to the requested direction, is presented for each of the 44 primary force measurements. The intercorrelations for the 44 exertions, and the correlations between the force exertions and the anthropometric dimensions are presented. Test-retest differences are presented for 11 of the subjects who completed the 44 force exertion measurements on two separate occasions.

121. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-72-16 April 1973 AD 767 206	COMBIMAN: COMputerized Biomechanical MAN-model	Kroemer, K.H.E.

Abstract: COMBIMAN is an engineering tool to represent geometry and physics of the man-cockpit system:

1. Reservoir of anthropometric information: "Body Form Analog"
2. Representation of body mechanics: "Biomechanical Analog"
3. Ergonomic model of man at his work station: "Ergonomic Analog"

This paper summarizes a literature review, a general discussion of computer models representing the geometry of the operator at his work station, the concept of the mathematical formulation, and the development phases of COMBIMAN.

122. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-72-19 July 1972 AD 747 190	Relationships Among Isometric Forces Measured in Aircraft Control Locations	Laubach, L.L., K.H.E. Kroemer & M.L. Thordsen

Source: Aerospace Medicine, 43:7, 738-742, 1972.

Abstract: Fifty-one male subjects participated in a study designed to measure the maximum ("peak") isometric forces that could be exerted at six locations of hand-operated aircraft controls. The subject sat in a simulated aircraft seat and exerted forces on a cylindrical handle. Forces were measured in two vertical and four to eight horizontal directions. Selected descriptive statistics are presented for each of the 44 force exertion measurements. The results show that the amount of force exorable depends decidedly on the location of the control and on the direction of force exertion. Correlations among the force exertions at the several locations were low, indicating that the forces exorable at a location must be determined experimentally rather than by regression analysis of other force data.

123. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-72-40 June 1973 AD A027 612	Involuntary Head Movements and Helmet Motions During Centrifuge Runs of Up to +6Gz	Kroemer, K.H.E. & K.W. Kennedy

Source: Aerospace Medicine, 44:6, 639-644, June 1973.

Abstract: Open-loop centrifuge runs reaching +6Gz were performed with 13 subjects wearing two different types of helmets: the foam padded standard HGU-2A/P, and the Gentex 129-2 with adjustable web suspension. Weights up to 20 ounces were attached at top and sides. The total maximal load was limited to 40 ounces and the largest lateral off-balance to 15 ounces.

During the centrifuge runs, each subject attempted to maintain his gaze at a target directly in front of him. Hence, no voluntary motion of the head should have occurred. Position of the helmet and of the head were recorded photographically at each G-level. From the photographs, data on actual movements of the head and of the helmet were extracted and subjected to a computer-aided analysis.

Involuntary angular head movements, as well as rotational displacements of the helmet on the head, are discussed in this paper in terms of pitch, roll, and yaw. Also described are linear changes in the vertical height of the subjects' eyes. Direction and amount of such motions are discussed with respect to the experimental variables: subjects, magnitude of +Gz, helmet type worn, mass of helmet assembly.

124. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-72-45 June 1972 AD A027 801	International Anthropometric Variability and Its Effects on Aircraft Cockpit Design	Kennedy, K.W.

Source: Proceedings, Symposium on National and Cultural Variables in Human Factors Engineering, Oosterbeek, The Netherlands, June 1972.

Abstract: Attention to the anthropometric characteristics of a consumer population plays an important role in the design of many products. To attain a high level of accommodation in highly complex systems such as air and spacecraft, severe economic and engineering trade-offs are encountered. Levels of accommodation are variable and, in all cases, very expensive. The subject of this paper is the high performance, single seat, military aircraft cockpit, and the problems to be dealt with in accommodating the anthropometric requirements of the foreign military user. With the airplane, we find that malaccommodation, when it occurs, not only produces a condition in which the product is not convenient to operate, but one in which the user's safety and the basic mission of the aircraft can be compromised.



125. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-72-46 December 1974 AD A011 537	Designing for Muscular Strength of Various Populations	Kroemer, K.H.E.

Abstract: Hand- and foot-operated controls are the input devices through which the operator effects the performance of manned systems. Selection of the type of control and its location within the reach envelope depend, to a large degree, on biomechanical parameters of all user populations (i.e., mainly on their body dimensions and on their strength characteristics, including motion stereotypes and lateral preferences). Muscular strength for control operation can vary significantly with age, sex, cultural origin, health, training, motivation, and other specific traits of the operator population. This paper discusses several of these variables and their biomechanical implications, and describes techniques and a regimen to design new equipment or modify existing equipment to conform to the strength characteristics of the operator populations.

126. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-72-75 May 1974 AD A011 581	Anthropometry and Kinematics in Crew Station Design	Kennedy, K.W.

Source: Proceedings of the Inter-Agency Conference on Management and Technology in the Crew Systems Design Process, K.D. Cross and J.J. McGrath (Editors), pp. 67-82, 1973.

Abstract: Attention to the anthropometric and kinematic characteristics of the aircrew member is essential to good cockpit design. Today, applied anthropology is performed by a variety of specialists in many industrial plants as well as research installations. The design problems are many in which anthropometric and kinematic variability must be accommodated. Many are crucial to the safety of the pilot and to the success of the mission. However, not everyone believes that human factors specialists have a rightful place in the design sequence.

The magnitude of the variability of body size and proportions among the national military populations of the world is startling to the designer. We find among all American military populations a similar but, of course, lesser variability. Yet, it is sufficiently large, and our systems sufficiently complex, so as to produce a difficult design situation. The condition of current anthropometric and kinematic data is reviewed. Insofar as concerns basic conventional anthropometry on our using military populations, there are ample current data. This, however, is a temporary condition. We find ourselves terribly short in functional anthropometric and kinematic data. This latter condition, it appears, was brought on by two developments: (1) the coming regular use of computers in cockpit design, and (2) the advent of very high performance/high g aircraft and their high acceleration cockpits.

127. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-72-93 May 1974 AD A011 580	The Effects of Personal Protective Equipment Upon The Arm-Reach Capability of USAF Pilots	Alexander, M. & L.L. Laubach

Source: Proceedings of the Inter-Agency Conference on Management and Technology in the Crew Systems Design Process, K.D. Cross and J.J. McGrath (Editors), pp. 225-233, 1973.

Abstract: The lack of published arm-reach data on Air Force flight personnel in actual cockpit situations presents manifest difficulties to the cockpit layout specialist. This paper discusses the results of a study to determine the arm-reach capabilities of aircrewmembers wearing heavy winter flight clothing, survival equipment, and restraint harnesses.

The study was conducted at Loring Air Force Base, Maine. The sample consisted of 16 male subjects (currently active Air Defense Command pilots). The subjects were selected to approximate closely the various height-weight categories in the ADC flying population. A specially designed apparatus was constructed to measure arm-reach capability. Each subject was measured under four conditions: (1) shirt-sleeved with the inertial reel unlocked; (2) shirt-sleeved with the inertial reel locked; (3) wearing his full assembly of flying gear (hereafter referred to as maximum assembly) including the underarm life preserver and parachute harness with the inertial reel unlocked; and (4) wearing the maximum assembly with the inertial reel locked.

The results of the study indicated that there are significant differences in arm-reach capability of pilots while in the shirt-sleeved and maximum flying assembly conditions throughout most of the spatial envelope.

128. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-72-127 May 1973 AD 767 201	Excursions of Head, Helmet and Helmet-Attached Reticle Under +Gz Forces	Kennedy, K.W. & K.H.E. Kroemer

Abstract: Open-loop centrifuge runs reaching +6Gz were performed with 13 subjects wearing two different types of helmets: the foam-padded standard HGU-2A/P, and the Gentex 129-2 with adjustable web suspension. Rigidly attached to the helmet was a lightweight reticle with its cross hair about 1-1/2 inches in front of the left eye. Masses were attached at top and sides of the helmets. The total maximal load was limited to 40 ounces, and the largest lateral off-balance to 15 ounces. During the centrifuge runs, each subject attempted to maintain his gaze at a target directly in front of him. Hence, no voluntary motion of the head should have occurred. Position of head, helmet, and reticle was recorded photographically at each G-level. From the photographs, data on actual excursions of the head, helmet, and reticle were extracted and subjected to a computer-aided analysis. Involuntary angular head movements, as well as rotational displacements of the helmet on the head, are discussed in this paper in terms of pitch, roll, and

yaw. Also described are linear changes in the vertical height of the subject's eyes. Reticle displacements are discussed as they occurred in a frontal y-z plane.

129. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1972	The Law and Our Responsibility	Garrett, J.W.

Source: Human Factors, 14:1, 3-6, 1972.

Abstract: Social and judicial reluctance to accept defectively designed products raises sharp questions concerning the human factors engineers' moral, ethical, legal, and personal responsibilities. This paper presents one human factors engineer's thoughts and opinions on these questions and illustrates situations where liability perhaps should and should not be personal.

130. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1972	Engineering Anthropology	Hertzberg, H.T.E. & K.H.E. Kroemer

Source: Human Engineering Guides to Equipment Design, 2nd ed., Van Cott & Kinkade, Editors, Chapter 11, U.S. Government Printing Office, Washington, D.C., 1972.

Abstract: This chapter presents basic data on human body-size, mobility, and strength. Although the bulk of the data stem from U.S. military populations, 50th male and female, because these have been more intensively studied than any others, some anthropometric data are also included for 35 or more non-U.S. populations to emphasize the view that human variation around the world must be considered by designers. Both "structural" (static) and "dynamic" (functional) body-size data are presented, with explanations of how these are used for design purposes. A section on muscle strength and muscle power summarizes extensive experimental data on the maximal and minimal forces exerted by subject samples in numerous test situations.

131. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-73-22 May 1973 AD A027 802	Effects of High G on Pilot Muscle Strength Available for Aircraft Control Operation	Kroemer, K.H.E.

Source: Proceedings of the 44th Scientific Annual Meeting of the Aerospace Medical Association, Las Vegas, Nevada, May 1973.



Abstract: Experiments were performed to gain information on the isometric strength capabilities of nine G-experimental subjects in centrifuge runs producing +3 and +5Gz. Their isometric strength was first established in the AMRL/HED biomechanical laboratory. Subsequently, each subject underwent a series of strength tests in the AMRL/DES human centrifuge (open loops mode). At +3 and +5Gz, the subjects exerted their maximal force forward, backward, to the left and right, up, and down to isometric force transducers located in the positions of stick, throttle, collective, sidearm controller, and of panel and overhead controls. The results indicate a clear pattern: within the experimental conditions investigated, higher Gz-loads decreased horizontal forces along the x axis (such as "forward" force at the center stick and the panel control, both in front of the subject). The ability to apply force against the direction of the acceleration (i.e., in the -Z direction, "down") generally increased while the ability to exert force in line with the acceleration (i.e., in the +Z direction, "up") decreased.

132. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-73-54 February 1975 AD A011 545	Human Force Capabilities for Operating Aircraft Controls at 1, 3, and 5 Gz	Kroemer, K.H.E.

Abstract: The maximum isometric forces adult male subjects could exert at eight locations of hand-operated aircraft controls were measured at 1, +3, and +5Gz. Forces were measured in two vertical and four to eight horizontal directions. Selected anthropometric dimensions were obtained on the subjects and compared with those from the 1967 USAF anthropometric survey of flying personnel. Summary statistics including the mean, standard deviation, coefficient of variation, symmetry, kurtosis, and selected percentiles are presented for each of the 60 force exertion measures.

133. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-73-73 September 1972 AD 164 340	Pilot Armreach and Cockpit Control Locator Machine	Alexander, M., J.W. Garrett & R.R. Riepenhaff

Abstract: This report describes in detail a test apparatus which is used to determine the capability of pilots to reach, grasp, and manipulate a control knob located at various angles and heights above the floor level. The apparatus consists basically of a simulated aircraft seat conforming to specification, a deck representing the floor of the aircraft cockpit, and an upright rod having a series of vertically-aligned knobs located at preselected angular positions.

134. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
May 1973	A Device to Evaluate the Reachability of Aircraft Hand-Operated Controls	Kennedy, K.W.

Source: Proceedings of the 44th Scientific Annual Meeting of the Aerospace Medical Association, Las Vegas, Nevada, May 1973.

Abstract: Data describing the inner and outer boundaries of minimum, 5th, 50th, and 95th percentile grasping reach capability have been obtained on a series of subjects, selected to be characteristic of the USAF flying population. Restraint techniques simulated a lap belt with shoulders back and shoulder harness inertia reel locked. The 5th percentile reach envelope, throughout which 95 percent of the population can reach, has been rotated artificially to represent the reach envelopes at seat-back angles from 10 to 70 degrees, and a constant seat-pan angle of +6 degrees. The reference point for the reach envelopes has been moved from Seat Reference Point (SRP) to a point 25 inches above SRP and the reach envelopes redescribed in terms of vertical and horizontal angles and linear distances from this new point.

A Cockpit Reach Evaluator has been fabricated. It is portable and designed to be placed in the aircraft seat and to measure the horizontal and vertical angles and distances from 25 inches above SRP to hand-operated controls. With the measurements obtained, it is a simple matter to ascertain immediately if a hand-controller is suitably located to be reached by 95 percent or more of the flying population.

Further studies will expand the usefulness of the Cockpit Reach Evaluator to include lesser levels of torso restraint and different methods of grasping and manipulating hand controls.

135. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-74-15 October 1973 AD A027 175	Three Dimensional Display of the COMBIMAN Man-Model and Work Space	Bates, F.J., Jr., S.M. Evans, H.E. Krause & H. Luming

Abstract: This report is a description of the status of the theoretical development of the COMBIMAN concepts and their application. Another report will cover the status of the computerization of these concepts.

Section 2 of this report explains the modeling technique for the man-model. At the present time, a model structure is employed that consists of 33 links, 19 flexible joints, six fixed parts, and nine peripheral points. The modeling technique allows the user to change the model structure easily (number of joints and links, and their arrangement).

Section 3 provides the theoretical background for the model application. For that reason, the necessary equations are derived that allow the user to compute, for instance, the coordinates of the peripheral and other model points

in a specified body position. At the present time, the user still has to specify all anthropometric dimensions and the angles in the joints to determine the model position. These computations represent, at the present time, the core of the COMBIMAN programs which are designed as CBMO3.

The COMBIMAN system is at an early stage of development at this time. Besides its use as an anthropometric reservoir, and as a tool to assemble the geometry of a human analog and a surrounding workstation, the COMBIMAN system is planned to predict and display human performance under various task requirements and environmental conditions. As a first step in that direction, Section 3 describes the theoretical background and techniques for the prediction of human attitudes in a specified situation. The basic concept is open ended as we hope to extend it in the future to predict motion patterns and other capabilities by expanding rather than revising the basic concept.

Section 4 deals with a theory and techniques of predicting the reach capability of a human operator. The techniques are based on the principles of the geometry model and the techniques applied to predict human attitudes. It should be noted here that the reach analysis is an application based on the fundamental COMBIMAN concepts rather than an additional, independent, and technically unrelated analysis. This is in line with our intention of making COMBIMAN a unifying concept of human form and capability rather than to develop a conglomerate of computer programs.

The human position prediction and reach analysis are subject to computerization in a future phase of COMBIMAN implementation.

136. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-74-17 April 1975 AD AO10 453	Arm-Reach Capability of USAF Pilots as Affected by Personal Protective Equipment	Laubach, L.L. & M. Alexander

Source: Aviation, Space, and Environmental Medicine, 46:4, 377-386, April 1975,

Abstract: Thirty-two USAF pilots participated in a study to determine the effects of personal protective equipment upon arm-reach capability. The reach envelope of each pilot was measured under two experimental conditions: (1) shirt-sleeved with the inertial reel unlocked; and (2) wearing complete winter flying assembly with the inertial reel locked. Selected descriptive statistics are presented for each of five angular positions. Arm-reach envelopes for various percentile values obtained for the two experimental conditions at 10 knob distances from the deck are shown. The results indicate that there are significant practical differences in arm-reach capability between the shirt-sleeved and the complete winter flying assembly conditions.



137. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-79-102 February 1976 AD A025 240	Sampling and Data Gathering Strategies for Future USAF Anthropometry	Churchill, E. & J.T. McConville

Abstract: Beginning with a comprehensive review of anthropometric resources already available, this report serves as a guide to more refined and less costly methods of acquiring needed anthropometric data to meet changing military requirements and to accommodate changing military populations. Many sampling schemes are described and evaluated for their utility in meeting specific USAF needs. Various measurement and sampling errors are discussed and the effects of each type of error on the statistics of major importance in design problems are explained.

The authors offer a definition of adequate accuracy based on a detailed statistical analysis and demonstrate that such accuracy can be obtained from random samples of 350 and matched samples of much fewer subjects. They suggest that with the completion of currently on-going anthropometric surveys no further data-gathering of U.S. military personnel on a massive scale need be undertaken.

A multifaceted plan for the future acquisition of USAF anthropometric data is recommended. The plan incorporates specific steps designed to update basic population data, follow and project secular trends, and devise surveys tailored to obtain specific task-oriented information.

138. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-74-137 DOT HS-801 430 March 1975 AD A016 485	Investigation of Inertial Properties of the Human Body	Chandler, R.F., C.E. Clauser, J.T. McConville, H.M. Reynolds & J.W. Young

Abstract: Knowledge of the anthropometric parameters of the human body is essential for understanding of human kinetics and particularly for the design and testing of impact protective systems. Considerable information is available on the size, weight, and center of mass of the body and its segments. This report supplements existing information with data regarding mass distribution characteristics of the human body as described by the principal moments of inertia and their orientation to body and segment anthropometry. The weight, center of mass location, and principal moments of inertia of six cadavers were measured; the cadavers were then segmented, and the mass, center of mass, moments of inertia, and volume were measured on the 14 segments from each cadaver. Standard and three-dimensional anthropometry of the body and segments was also determined.

This report describes the mathematical rationale and the techniques of measurement in detail. Results of the investigation are given as individual data values as well as summary statistics.

139. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-75-18 July 1976 AD A029 402	Mass Distribution of the Human Body Using Biostereometrics	Herron, R.E., J.R. Cuzzi & J. Hugg

Abstract: As the new field of biostereometrics has become more widely known, the potential to use it for computing mass distribution from body shape and density data has attracted growing interest. Biostereometrics is the spatial and spatio-temporal analysis of biological form and function based on principles of analytic geometry. When applied to humans, it constitutes a modern approach to anthropometry. A suitable stereometric sensor is used to locate the three dimensional coordinates of points distributed over the body surface. The coordinates serve as input to a digital computer which is programmed to yield permutations of numerical or analog (graphical or physical) outputs as the application requires.

In the present study, stereophotogrammetry was used to obtain stereometric data in the form of Cartesian coordinates of six segmented human cadavers. Density data provided by the contractor (AMRL) were then used in conjunction with the stereometric data to generate mass, volume, center of mass, and principal moments of inertia about the principal axes of inertia with the aid of an IBM 360/50 digital computer.

This study was undertaken to further explore the viability of computing mass distribution from biostereometric data and the best available human density values. Only one part of what was a two-part study is reported here. Mass distribution of the same six segmented cadavers was determined experimentally in a companion study undertaken by Chandler et. al. (1975). Comparative analysis of the results obtained in the two studies is continuing, but a preliminary examination suggests that the biostereometric and pendulum-based measurements of mass distribution correlate very well. If further scrutiny bears out the preliminary findings, the basis for using biostereometrics to compute mass distribution in living humans will have been more firmly established. As more complete and more accurate human density data become available, results based on biostereometrics computation can be expected to come even closer to the "true" mass distribution values. With the growing use of digital computers for analytic and simulation purposes rather than simply as a statistical tool, the potential of biostereometrics for generating biomechanical and biomedical parameters warrants further study and implementation where appropriate.

140. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-75-32 May 1976	Muscular Strength of Women and Men: A Comparative Study	Laubach, L.L.

Abstract: Experiments were conducted to measure static muscular strength characteristics of women subjects and compare these results with similar data previously reported for males. Twelve measures of static muscular strength, 22 body-size measurements, and the somatotypes of 31 female subjects were investigated. Selected reports in the literature that have dealt with the

comparison of static and dynamic muscular strength of women and men are presented and discussed in some detail. The summary descriptive statistics for the strength measures were compared (tabularly and graphically) and percentage differences in strength between women and men reported. An analysis of the range and the average mean percentage difference in muscular strength capabilities is presented. The complete intercorrelation matrix for the 38 variables (including age) obtained in this research is shown.

141. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-75-38 March 1976	Head and Neck Cooling by Air, Water, or Air Plus Water in Hyperthermia	Kissen, A.T., W.C. Summers, W.J. Buehring, M. Alexander & D.C. Smedley

Source: Aviation, Space, and Environmental Medicine, 47:3, 265-271, March 1976.

Abstract: The effects of air, water, and air plus water head cooling on thermoregulatory responses and human operator performance were studied in nonacclimatized, heat-exposed men. Forty chamber exposures (46°C, 30 mm Hg water vapor pressure) were conducted under noncooled and the aforementioned subconditions of head cooling. Five subjects, exposed for 80 minutes, were monitored for mean skin and rectal temperatures, heart rate, sweat loss, and compensatory tracking performance. A modified Air Force helmet shell provided facial air ventilation (24°C) at 8 cfm. Eight interconnected neoprene modules fastened beneath a helmet liner provided water cooling (200C at 0.9 liters/minute). Tracking performance was unchanged across conditions. Elevation of rectal temperature and heart rate, sweat loss, and Physiological Index of Strain were significantly reduced by each condition of head cooling. Air is as effective as water as a cooling agent. Air ventilation acts synergistically with water cooling in reducing physiological strain. Relative merits of each approach to head cooling, in an operational context, are discussed.

142. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-75-51 November 1975 AD A027 516	Anthropometric Sizing Program for Oral-Nasal Oxygen Masks Based on 1967 U.S. Air Force Survey Data	McConville, J.T. & M. Alexander

Source: Aviation, Space, and Environmental Medicine, 46:11, 1383-1389, November 1975.

Abstract: A new sizing program for oral-nasal masks, based on total facial length, has been developed through an analysis of the 1967 USAF anthropometric survey head and face data. A four-size series of three-dimensional face forms has been sculpted based on this sizing program as a design aid for sizing such



masks. This report includes a discussion of the theoretical and practical aspects of the sizing analyses and procedures, and establishes design limits and procurement tariffs for the four sizes of masks. The MBU-12/P oxygen mask, an oral-nasal, pressure-demand type of mask, has been fabricated in accordance with this sizing system using the face forms as sizing guides. The results obtained during fit-tests using 66 USAF personnel as subjects are described. The authors concluded that the dimensional sizing of the oral-nasal oxygen mask facepieces is valid for USAF flight crews.

143. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-75-111 March 1976 AD A025 773	Paths of Movement for Selected Body Segments During Typical Pilot Tasks	Ayoub, M.M., S. Deivanayagam & K.W. Kennedy

Abstract: This report describes the geometry of paths of motion for body segments when the hand travels between selected control locations within an aircraft cockpit. The controls selected for this study were the stick, throttle, overhead, panel, side-arm, and hatch. The control locations (start and endpoints of the hand travel) were selected to represent both conventional and high acceleration type aircraft cockpits. In addition, three different seat back rest angles (13, 30, and 65 degrees) were employed to represent the conventional and high acceleration seat configurations. To adequately describe the movements of all body segments, the following landmarks on the body were studied using photogrammetric techniques: Nasion, Cervicale, Suprasternale, Acromion, Shoulder Joint Center, Elbow Joint Center, Wrist Center, Grip Center, and Greater Trochanter.

This study was performed as part of the COMBIMAN (COMputerized BIomechanical MAN-model) program of Aerospace Medical Research Laboratory. When completed, COMBIMAN will be a computer-controlled "manikin" representing a pilot under cockpit environment. This model, as a "Biomechanical Analog" of the pilot, requires as input, certain kinematic data pertaining to the movement of body segments within a cockpit doing typical pilot tasks. This effort was undertaken to provide this movement data for the primary aircraft controls from which kinematic information can be developed.

144. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-75-120 May 1976 AD A072 892	Comparative Muscular Strength of Men and Women: A Review of the Literature	Laubach, L.L.

Abstract: The results from nine separate studies reporting comparable static and dynamic muscle strength measurements between men and women have been reviewed. The statistical data from these studies are presented in graphical and tabular form. Each graph illustrates, when appropriate, the mean,  $\pm$  one standard deviation, and the mean percentage difference between men and women for the given measurement.

The following differences in strength measurements were observed: (a) upper extremity strength measurements in women were found to range from 35 to 79 percent of men, averaging 55.8 percent; (b) lower extremity strength measurements in women ranged from 57 to 86 percent of men, averaging 71.9 percent; (c) trunk strength for women ranged from 37 to 70 percent of men, averaging 63.8 percent; (d) dynamic strength indicators revealed that women were from 59 to 84 percent as strong as men, with an average of 68.6 percent.

In view of the wide range of mean percentage differences in muscle strength measurements between men and women, the author stresses the importance of exercising extreme care in making extrapolations from such data and recommends a method for making such extrapolations when the absence of direct measurements make this necessary.

145. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
SAE Paper No. 750424 February 1975	Mass Distribution Properties of the Male Cadaver	Reynolds, H.M., C.E. Clauser, J.T. McConville, R.F. Chandler & J.W. Young

Source: Presented at the Society of Automotive Engineers (SAE), Automotive Engineering Congress and Exposition, Detroit, Michigan, February 1975.

Abstract: Using six male cadavers, three-dimensional measurements were made of the mass distribution properties of the human body and its 14 primary segments. Data collected include anthropometry, mass, center of mass, and the principal moments of inertia. The principal moments of inertia were computed using a 3 x 3 matrix of values derived from simple pendulum measurements about six non-parallel axes.

Anatomical segmentation procedures used are emphasized and compared with those in previous investigations. In addition, comparisons of the measured data with extant data in the literature on the whole body and its segments are presented and discussed.

146. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AGARD-AG-205 April 1975 AD A010 674	A Review of Anthropometric Data on German Air Force and United States Air Force Flying Personnel 1967-1968	Grunhofer, H.J. & G. Kroh

Abstract: The study contains anthropometric data of GAF and USAF flying personnel. The hitherto unpublished data of German Air Force flying personnel were taken from measurement programs performed in 1967 and 1968 by a team of

the German Air Force Institute of Aviation Medicine, Furstenfeldbruck, Germany (GAF IAM). They include 153 different body dimensional data of more than 1400 subjects. The data for USAF flying personnel were taken from measurements of 2420 subjects in 1967. These data represent the latest state of anthropometric surveys of American flying personnel.

For each body dimension, the following detailed information is given:

- The definition, written and illustrated, of body dimension to be measured.
- The frequency of certain ranges.
- A breakdown of GAF and USAF data in percentile, permitting comparison.
- Essentials on the statistics of data distribution.

To facilitate further anthropometric studies, the correlation matrix of GAF data has been added in the appendix. The tables contain the correlation coefficients of any anthropometric body dimension with any other listed in this study.

147. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-76-29 May 1976 AD A025 750	Statistical Concepts in Design	McConville, J.T. & E. Churchill

Abstract: In seeking a manageable way to deal with variations for a large range of body sizes, it is a common practice for designers to construct drafting board manikins, three-dimensional forms, or computer simulations as human analogues. Often these analogues are based upon 5th, 50th, or 95th percentile values. Limitations of this approach are discussed in this paper which demonstrate fallacies underlying the assumptions that (1) the proportionality of various sized individuals is the same, and (2) percentiles for body dimensions are additive.

Focusing on the 5th and 95th percentile body forms where deviations in size and proportionality are most severe, the report recommends an improved approach to portray the body size of these segments of the population in design problems. A statistical analysis is made of the tails of the height-weight distribution to demonstrate the usefulness of subgroups or regression values. It is suggested that, for many design purposes, subgroup or regression values be used which would maintain statistical integrity in simulations and, at the same time, portray the ends of the distribution more accurately than is presently done.

148. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-76-30 July 1976 AD A032 402	COMputerized BIomechanical MAN-model	McDaniel, J.W.



Source: Presented at the Industrial Engineers Association/Human Factors Society Congress, College Park, Maryland, July 1976.

Abstract: The COMputerized BIomechanical MAN-model (called COMBIMAN) is a computer interactive graphics technique for workplace design. This model allows a designer to manipulate a three-dimensional man form of variable anthropometry and to design a workplace around this man-model by means of a light pen while sitting at a CRT. While originally intended for aircraft design and evaluation, the general format of the model allows it to consider virtually any workplace configuration. Among the functions of COMBIMAN described in this paper are: (1) the capability to represent the anthropometry of many populations, (2) the capability to exercise variations of body proportions, (3) interaction with a workplace to determine complex hand and foot reach envelopes, (4) reaching to controls in a realistic path of motion, (5) evaluating workplace task incompatibilities, (6) mapping the fields-of-view of the man-model within a workplace, and (7) determining distances between any points in a three-dimensional workplace. Although the COMBIMAN is only displayed or printed in a two-dimensional format, the man-model and workplace exist and interact in three-dimensional space. The model can be used to evaluate an existing or theoretical workplace with equal ease and precision.

149. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-76-32 July 1976	Anthropometric Assessment of Mass Distribution Characteristics of the Living Human Body	McConville, J.T. & C.E. Clauser

Source: Presented at the Industrial Engineers Association/Human Factors Society Congress, College Park, Maryland, July 1976.

Abstract: Techniques have long been sought for estimating accurately the weight, volume, location of the center of mass, and the principal moments of inertia of segments of living human beings. In a recently completed Federal Aviation Administration-United States Air Force study during which these parameters were measured on 14 segments of six male cadavers, stereophotographs of each segment were made. Estimates by the Biostereometrics Laboratory, Texas Institute of Rehabilitation of the same mass distribution characteristics measured on the cadavers were made by analyses of the photographs. Results of the cadaver and stereometric studies are summarized and compared. Techniques are suggested for measuring mass distribution characteristics of living human beings for permitting the collection of such data on samples adequate to describe population parameters.

150. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-76-71 November 1976 AD A036 276	Evaluation of a Face Cooling Device Integrated with the Standard HGU-Type USAF Flight Helmet	Kissen, A.T., M. Alexander, D.C. Smedley, W.J. Beuhring, S.L. Ward & D.H. Lowe

Abstract: The effectiveness of face cooling in ameliorating the physiological impact of a moderate-to-severe, operationally realistic hyperthermic stress was demonstrated in a previous paper. Justification of the principle prompted efforts to develop a cooling device of improved design which, aesthetically and operationally, interfaced with the HGU-26/P standard Air Force helmet. A single-piece, fiberglass partition was form-fitted to and mounted on the shell with sufficient elevation to provide an air plenum between the two. Ventilating air of 23°C at 0.17 m<sup>3</sup>/minute (6 cfm) entered the plenum from the side and exited over the anterior edge of the shell. Tracking performance was unchanged with face cooling; however, significant reduction in physiologic strain was demonstrated. Elevations of rectal temperature and heart rate were suppressed by 46 percent and 45 percent, respectively. Sweat loss was reduced by 43 percent. Structural modifications of the helmet to accommodate the device are minimal.

151. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-77-1 October 1977 AD A047 314	The AMRL Anthropometric Data Bank Library: Volumes I-V	Churchill, E., P. Kikta & T. Churchill

Abstract: This report describes the contents of Volumes I-V of the AMRL Anthropometric Data Bank Library. Volumes I-IV consist of the data from four major USAF anthropometric surveys: the 1950 and 1967 surveys of flying personnel, the 1968 survey of USAF women, and the 1965 survey of male personnel. Volume V contains correlation coefficients based on these surveys, the 1946 survey of Army female separatess, the Health Examination Survey of 1960-62, and the law enforcement officer survey of 1974.

Included are a description of the tape formats, definitions of the measurement variables, and XVAL listings for each tape. Names and serial numbers of all subjects have been omitted to preserve the confidential nature of the records.

152. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-77-2 May 1978 AD A058 616	Intercorrelations of Anthro- pometric Measurements: A Source Book for USA Data	Churchill, E., P. Kikta & T. Churchill

Abstract: Correlation matrices based on data from USAF anthropometric surveys of women (1968, 127 variables), flying personnel (1950, 128 variables; 1967,

190 variables), and basic trainees (1965, 161 variables); a U.S. Army survey of women separatess (1946, 60 variables); the Health Examination Survey of civilian adults (1960-1962, 18 variables); and a survey of law enforcement officers (1974, 23 measurements) are presented for use by engineers who need them in solving design problems and for anthropologists and statisticians whose analyses and understanding of the interrelationships of body size data depend significantly on these coefficients. Sample sizes in these surveys ranged from almost 2000 upward. Definitions and basic univariate summary statistics are presented for all variables involved. Appendices contain a glossary of anatomical terms, tables for establishing confidence limits for the correlation coefficients presented here, computer programs used in preparing this report, and an index by name, anatomical type, and anthropometric technique. A bibliography is also included.

153. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
ADTC-TR-77-41 May 1977 AD B018 812L	Human Factors Evaluation of the A/S 32K-4 Bomb Lift Truck	Heckart, S.A., M. Alexander & J.T. McConville

Source: Development Test of the A/S 32K-4 Bomb Lift Truck, Technical Report ADTC-TR-77-41, 3246th Test Wing, Armament Development and Test Center, Eglin Air Force Base, May 1977.

Abstract: This report presents the results of the development test of the A/S 32K-4 Bomb Lift Truck (BLT) to verify vehicle performance, transportability, utility, and maintainability (limited); and to assess human factors criteria. The BLT passed all performance tests with the exception of the parking brakes not holding upon engine shutdown when parked headed up a 0.14-rad (8-degree) slope and loaded with a 1,860 kilogram (4,100 pound) test load.

The BLT was deficient from the human factors engineering standpoint because of the design of the cab, operator controls, lighting, visual access, and safety features. Evaluation of exhaust gas during BLT operation in a standard munition igloo revealed acceptable gas levels with the igloo doors open; however, carbon monoxide and nitric oxide levels approached their respective threshold limiting values (TLV) within 11 minutes when the igloo doors were closed. Noise emission levels were acceptable; however, for operations inside an igloo, ear protection was recommended for personnel working in the igloo for more than two hours per day.

154. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-77-44 September 1977 AD A098 458	Selected Design Parameters for Reclining Seats Based on Engineering Anthropometry	Ayoub, M.M., S. Deivanayagam & K. Kennedy

Abstract: This report discusses selected engineering anthropometric design criteria for reclining cockpit seats. The reclining back-rest positions



selected were 13 degrees, 27 degrees, 51 degrees, and 65 degrees from the vertical line through the seat reference point (SRP). Two seat pan angles of 10 degrees and 20 degrees were utilized. Three seating Components were considered in this report: head rest, arm rest, and foot rest. The specific engineering anthropometric design parameters addressed were: (a) head rest hinge point location, (b) arm rest location and orientation in space as the seat reclines, (c) location of foot rests, and (d) synchronization of arm rest movement with back rest inclination.

155. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-77-50 July 1978 AD A060 312	Reach Capability of Men and Women: A Three-Dimensional Analysis	Kennedy, K.W.

Abstract: This report contains descriptions of the outer and inner boundaries of the 5th, 50th, and 95th percentile grasping-reach envelopes of men and of women. The reach envelopes are intended to guide the placement of critical hand operated controls for the seated operating and working body positions. The most important envelope is the 5th percentile, since it describes that past which 95 percent of the using population can reach. Thus, a controller located at the boundary of this envelope can be reached by an equivalent percentage of the male or female adult populations. A critical review of previous investigations of arm reach and a description of the Aerospace Medical Research Laboratory's Grasping-Reach Measuring Device are presented. The data-gathering procedures and the methods of analyses are included. Applications of the data are also discussed. Data are presented in both graphic and tabular form. Vertical (X-Z) and (Y-Z) planes, and horizontal (X-Y) planes through the various percentile envelopes are presented.

Appendices are included, reporting (1) comparisons between original and final data, (2) reach envelopes for a 50/50 mixed adult male and female using population, and (3) anthropometric data on subject populations.

156. REPORT NUMBER/DATE	TITLE	AUTHOR(s)
AMRL-TR-77-77 November 1977 AD A052 893	Comparative Anthropometry of Air Standardization Coordinating Committee Personnel for Equipment Design: Helmets	McConville, J.T. & C.E. Clauser

Abstract: The objective of this report is to demonstrate that the comparability of body-size distributions of aircrew personnel of Air Standardization Coordinating Committee (ASCC) member nations is such that protective equipment sized and designed to fit personnel of one member nation will fit personnel of all member nations as well. The research reported in this publication compares the available anthropometry of the head and face of member ASCC nations, demonstrates their similarities, and tests the theoretical suitability of a Royal Aircraft Establishment (RAE) sizing program for helmets to accommodate U.S. Air Force (USAF) personnel.

157. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-77-94 February 1978 AD A060 114	Establishing Criteria for Assigning Personnel to Air Force Jobs Requiring Heavy Work	Ayoub, M.M., R.F. Powers, N.J. Bethea, B.K. Lambert, H.F. Martz & G.M. Bakken

Abstract: This report provides a plan which, when executed, will result in an improvement of the Air Force's present capabilities to select and assign personnel to Air Force specialty Codes (AFSCs). This will be accomplished through the development of a validated objective criterion, as proposed, with which the Air Force can reliably evaluate the compatibility of an individual's physical capacities with the physical demands of the various Air Force Specialty Codes. The validity of the criterion will be measured by the individual's ability or inability to successfully perform a selected set of well defined, demanding tasks within an Air Force Specialty Code.

The method of accomplishment is divided into four phases. Phase I is task oriented. In this phase each AFSC is surveyed to identify the tasks which require significant physical demands. These tasks are quantified, using an appropriate physical unit through the use of task analysis, such that an accurate assessment of the demands can be made. From this list of tasks for each AFSC, a set of tasks known as performance criteria tasks (PCTs) will be selected. An individual's performance on these PCTs will determine whether or not the individual is successful or unsuccessful with that AFSC.

Phase II involves the identification of tests which can be used at the Armed Forces Examination and Enlistment Station (AFEES) and Basic Military Training (BMT) Center for predicting the individual's success within jobs having varied degrees of heavy physical demands.

Phase III involves the definition, hazard evaluation, and procurement of the equipment needed for task analyses, AFEES and BMT testing, and for testing during the longitudinal validation phase (Phase IV).

Phase IV involves the finalization and validation of the assignment criteria. Samples of incoming personnel will be tested and categorized according to their tested physical capabilities. The success of these individuals will be monitored over an extended time period (approximately 18 months) such that the AFEES and BMT tests can be validated as successful predictors of success or failure on heavy jobs.

The benefits derived by the Air Force from this capability are a reduction in early discharges due to the inability of the individual to physically qualify for an AFSC after enlistment; a reduction in training costs, both initial and cross-training, due to a reduction in the probability of an individual's eventual failure in the AFSC; a reduction in injury-related costs due to a reduction in the number of individuals performing physical demands near or exceeding their maximum safe capability; and a reduction in operating costs by improving the workforce capability relevant to the tasks' physical demands.

158. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFOSR-TR-77-0911 January 1977 AD A042 890	A Foundation for Systems Anthropometry, Phase I	Reynolds, H.M.

Abstract: The purpose of the present program is to conduct basic research into the properties and requirements of three-dimensional dynamic anthropometry. In essence, the research has the expressed goal of inductively describing the linkage of the whole body for predicting body motion in three-dimensional dynamic computer simulations. This effort may be divided into three subsidiary tasks dealing with (1) the identification, location, and relationship of externally and internally "stable" landmarks; (2) the definition of whole body and segment anatomical axes systems; and (3) the quantitative description of body motion with probabilistic characteristics of each major joint center of mobility.

This report contains several sections that address different aspects of the research goal. They are:

1. Geometric errors produced in the definition of an anatomically-based coordinate system using anthropometric data;
2. Stereo-radiographic methodology for measuring three-dimensional location of surface and internal (skeletal) landmarks;
3. Body-sizing scheme describing by height and weight different categories of individuals within the population;
4. Three-dimensional skeletal geometry of the adult pelvis for small, medium, and large individuals in the U.S. population;
5. Statistical and probabilistic properties of three-dimensional anthropometric data measured in 280 flight attendant trainees;
6. Geometric model of a cored frustum of a right elliptical cone to estimate the inertial properties of body segments;
7. Technique for the measurement of striated muscle density for geometric model input.

In conclusion, the role that systems anthropometry can take in handling real-world design problems that require human interface appears to be significantly larger than a comparable position for traditional anthropometry. The practicality of the new anthropometric techniques of systems anthropometry must, however, be demonstrated.



159. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
TAC Project 74E-057T July 1977	Validation of Sizing/Design of U.S. Army Chemical Protective Overgarment for Use by USAF Personnel	Alexander, M. & J.T. McConville

Source: Chemical Warfare Equipment and Procedures Special Project, TAC Project 74E-057T, Guidry and Schick, Annex A, Appendix 2, USAF Tactical Air Warfare Center, Eglin Air Force Base, Florida, July 1977.

Abstract: This report documents the results of a sizing and fit-test evaluation of a two-piece garment (jacket and trousers) designated as Suit, Chemical Protective, developed by the U.S. Army to be used by USAF ground support personnel. A total of 37 subjects, drawn from on-duty USAF personnel largely engaged in ground support tasks, were used in the fitting trials. Garment modifications are suggested, and a procurement tariff for the garment assembly is presented.

160. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
TAC Project 74E-057T July 1977	Sizing/Design Validation Test of Personal-Protective Equipment for Chemical Warfare	Alexander, M. & J.T. McConville

Source: Chemical Warfare Equipment and Procedures Special Project, TAC Project 74E-057T, Guidry and Schick, Annex A, Appendix 3, USAF Tactical Air Warfare Center, Eglin Air Force Base, Florida, July 1977.

Abstract: This report describes sizing and fitting trials of three items of protective clothing for females and one type of protective glove for males. The equipment tested on females was as follows:

1. Suit, chemical protective for ground support personnel.
2. Gloves, toxicological agent protective.
3. Glove set, chemical protective.

The glove tested on males was an A type glove. Test procedures, results, and procurement tariffs are presented for each item.

161. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
TAC Project 74E-057T July 1977	Sizing Evaluation of CW Warfare Eight-Size Commercial Overglove (Edmont-Wilson, Model 29-84h) for Flight Personnel	Alexander, M. & J.T. McConville

Source: Chemical Warfare Equipment and Procedures Special Project, TAC Project 74E-057T, Guidry and Schick, Annex B, Appendix 2, USAF Tactical Air Warfare Center, Eglin Air Force Base, Florida, July 1977.

Abstract: A sizing and fit evaluation of an eight-size, neoprene, chemical warfare glove was conducted, and the results are documented in this report. A total of 33 on-duty flight personnel were used in the fitting trials. Test procedures were described and a recommended procurement tariff is presented.

162. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
TAC Project 74E-057T July 1977	Validation of Sizing of Chemical Warfare (CW) Nine- Sized United Kingdom Undergarment for Use by USAF Crewmembers	Alexander, M. & J.T. McConville

Source: Chemical Warfare Equipment and Procedures Special Project, TAC Project 74E-057T, Guidry and Schick, Annex E, Appendix 2, USAF Tactical Air Warfare Center, Eglin Air Force Base, Florida, July 1977.

Abstract: The sizing and fit test evaluation of a one-piece, long-sleeved, disposable undergarment, designed to provide protection against certain chemical warfare agents, is documented in this report. The garment was developed in the United Kingdom for pilots. A total of 37 predominantly military subjects, 26 of whom were on current flying status, were used in the fitting trials. It was concluded that the United Kingdom nine-size garment was adequately sized to accommodate USAF aircrewmembers.

163. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFOSR-TR-78-1160 HSRI 78-11 March 1973 AD A059 053	A Foundation for Systems Anthropometry - Phase II	Reynolds, H.M., J.R. Freeman & M. Bender

Abstract: This report describes the experimental procedures utilized at the Highway Safety Research Institute and The Civil Aeromedical Institute in an investigation of the landmarks, axes systems, and joint properties necessary to describe the human body in three-dimensional space. The study at HSRI utilized three fresh cadavers in the study of the spatial relationship between internal and external landmarks in the lumbar/pelvic/femur region of the body. In addition, the motion characteristics of the hip joint in flexion-extension, abduction-adduction, and internal-external rotation were investigated. The study at CAMI is using 150 male and 150 female osteological specimens from the Hamann-Todd skeletal collection to investigate the three-dimensional variability of landmark locations in the pelvis. Data are presented in tabular and graphical forms.

In general, the results of this program to date can be summarized as follows:

1. Biological variability must be considered as a set of probabilistic phenomena in deterministic biomechanical models.
2. Body position and mobility must be considered simultaneously in three-dimensional space.
3. Data collection and analysis must incorporate the use of anatomical frames of reference defined by functionally significant landmarks in the skeletal system.
4. Body position can be defined by the location of anatomical frames of reference, and body mobility can be defined by relative motion between adjacent anatomical frames of reference.

164. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-78-38 July 1978 AD A060 393	Editing Procedure for Anthropometric Survey Data	Kikta, P. & T. Churchill

Abstract: Described in this report are two computer programs designed to edit large masses of anthropometric survey data. The XVAL (eXtreme VALues) program scans for gross errors by sorting out the ten lowest values in a given set of data for visual inspection. The EDIT (EDITing) program, a technique for sifting data more finely, tests each datum for each subject by comparing the measured value with a predicted value obtained from regression equations and flagging those which deviate from set limits.

Detailed descriptions of input routines and computer output are liberally illustrated at every step. Instructions for the use of these programs are given to enable programmers to apply them to their own data. Computer print-outs of the entire XVAL and EDIT programs, applied to actual data, are included as appendices.

The authors emphasize the limitations of these programs by pointing out that however sophisticated the editing routines, they can only serve to discover, identify, and flag possible error. It is left to the experienced professional to confirm the deviant value as an error, assess its nature, and decide whether to eliminate, correct, or replace it.

165. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-78-111 October 1978 AD A061 390	Anthropometric Resources Versus Civilian Needs	McConville, J.T. & C.E. Clauser

Abstract: The need to gain useful access to the wealth of extant body size information prompted the Anthropology Group at Wright-Patterson Air Force Base to initiate, in 1973, the development of the Aerospace Medical Research Laboratory's (AMRL) Anthropometric Data Bank. This facility was designed to



incorporate in comparable format, and at a single center, the raw data from as many anthropometric surveys as are available, so that they could be recalled and reanalyzed for specific purposes, as needed. It was also recognized that such a repository would serve an important function in assuring that anthropometric survey data would remain available even though the principal investigator or the sponsoring agency may have lost interest in maintaining them. Over the past five years, the data bank has grown (and continues to grow) so that it now comprises a uniquely comprehensive source of such data.

166. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-78-112 May 1978 AD A061 865	Aerospace Medical Research Laboratory's Pilot Strength and Endurance Screening Program	McDaniel, J.W.

Abstract: Since women pilots in the Air Force are restricted from flying combat aircraft (i.e., fighters), they are being assigned primarily to fly the multi-engine cargo-type aircraft. These older generation aircraft have mechanical controls with limited power assist, and are physically demanding to pilots under certain conditions.

This report presents some background data on aircraft specifications, aircraft control forces, and the comparative strength and endurance capabilities of male and female pilots. A plan is presented to gather additional data on pilot strength capabilities, as well as the control forces required to fly typical aircraft.

167. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape March 1978 AD A056 154	The AMRL Anthropometric Data Bank Library: Volume I-- The 1968 Survey of Air Force Women	N/A

Abstract: A survey of women of the Air Force was made in the spring of 1968 by the Anthropology Branch, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, and the Anthropology Research Project (then at Antioch College, Yellow Springs, Ohio). A description of the survey and the results are published in Anthropometry of Air Force Women, by Clauser et al., AMRL-TR-70-5 (AD 743 113), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, 1972. Data for age (variable 1), 123 body size measurements (variables 2-124), and grip strength (variable 125) were obtained from a sample of 1905 women. Thirteen measurements were repeated on 1513 subjects with the subjects wearing foundation garments (variables 126-138). The contents of this tape are also described along with Volumes II-V of The AMRL Anthropometric Data Bank Library in the report The AMRL Anthropometric Data Bank Library: Volumes I-V, by Churchill, Kikta, and Churchill, AMRL-TR-77-1, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, October 1977. This contains the complete

survey in the fully edited form. Names and serial numbers of all subjects have been omitted to preserve the confidential nature of the records.

168. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape March 1978 AD A056 155	The AMRL Anthropometric Data Bank Library: Volume II-- The 1967 Survey of USAF Flying Personnel	N/A

Abstract: The 1967 survey was conducted during the first three months of 1967. It was planned and conducted under the direction of Charles E. Clauser, then Chief of the Anthropology Branch of the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, with the collaboration of Milton Alexander, Kenneth Kennedy, Jack Henninger, and John Garrett at AMRL and Edmund Churchill and Lloyd Laubach of the Anthropology Research Project, Yellow Springs, Ohio. Measuring was carried out at almost 20 bases spread over the country. Summary statistics and a description of measuring techniques for most variables are reported in A Review of Anthropometric Data of German Air Force and United States Air Force Personnel, 1967-1968, edited by H.J. Grunhofer and G. Kroh and published as AGARD-AG-205, 1975. The contents of this tape are also described along with Volume I and Volumes III-V of the AMRL Anthropometric Data Bank Library in the report The AMRL Anthropometric Data Bank Library: Volumes I-V, by Churchill, Kikta, and Churchill, AMRL-TR-77-1, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, October 1977. This contains the complete survey in its fully edited form. Names and serial numbers of all subjects have been omitted to preserve the confidential nature of the records.

169. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape March 1978 AD A056 156	The AMRL Anthropometric Data Bank Library: Volume III-- The 1965 Survey of USAF Personnel	N/A

Abstract: A survey of USAF male personnel was conducted during the spring and summer of 1965. The survey was planned under the direction of H.T.E. Hertzberg and later by Milton Alexander and C.E. Clauser of AMRL and Lloyd Laubach of the Anthropology Research Project. In the first portion of the survey, 549 officers (396 pilots and navigators; 153 non-flyers), four Warrant Officers, and 683 enlisted men were measured. In the second half, 2632 men (2203 white, 412 black, 17 other) undergoing basic training and one Sergeant were measured at Lackland Air Force Base. Of this Lackland group, 106 men had ranks other than basic trainee. The contents of this tape are also described along with Volumes I, II, IV, and V of the AMRL Anthropometric Data Bank Library in the report The AMRL Anthropometric Data Bank Library: Volumes I-V, by Churchill, Kikta, and Churchill, AMRL-TR-77-1, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, October 1977. This contains the complete survey in its fully edited form. Names and serial



numbers of all subjects have been omitted to preserve the confidential nature of the records.

170. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape March 1978 AD A056 157	The AMRL Anthropometric Data Bank Library: Volume IV-- The 1950 Survey of USAF Flying Personnel	N/A

Abstract: The USAF's first major anthropometric survey was conducted during the spring and summer of 1950. It was organized and directed by H.T.E. Hertzberg and Gilbert Daniels and reported on in Anthropometry of Flying Personnel--1950, WADC TR-53-321, by Hertzberg, Daniels, and Churchill (AD 47 953). The survey was carried out at 14 bases in Massachusetts, Michigan, Colorado, Washington, California, Texas, and Louisiana. The measuring team consisted of Antioch College students trained by Hertzberg and Daniels. The original statistical analyses were the initial activity of the Anthropology Research Project. The results reported in WADC TR-52-321 were carried out prior to the availability of modern computer facilities. Since publication of that report, the data have been modernized. Millimeter figures for most variables originally recorded but not punched were incorporated into the data. Some 63 of the original 4063 subjects with measuring body size values have been deleted and the data thoroughly edited. This tape includes data for 4000 subjects and 161 variables: variables 1-132 are body size values, 133 is age, 134-146 are somatotype ratings (those listed as somatotype are ratings done by Dupertuis using Sheldon's method), see Dupertuis, C.W. and Irvin Emanuel, A Statistical Comparison of the Body Typing Methods of Hooton and Sheldon, WADC TR-56-366 (AD 97 205). The contents of this tape are also described along with Volumes I-III and Volume V of the AMRL Anthropometric Data Bank Library in the report, The AMRL Anthropometric Data Bank Library: Volumes I-V, by Churchill, Kikta, and Churchill, AMRL-TR-77-1, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, October 1977. This contains the complete survey in its fully edited form. Names and serial numbers of all subjects have been omitted to preserve the confidential nature of the records.

171. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
NASA Ref. Pub. 1024 July 1978 N79-11734	Anthropometric Source Book Volume I: Anthropometry for Designers	McConville, J.T., I. Tebbetts, L.L. Laubach & E. Churchill

Abstract: This three-volume publication brings together a large mass of anthropometric data which define the physical size, mass distribution properties, and dynamic capabilities of U.S. and selected foreign adult populations. It is a comprehensive source of specific information as well as a guide in the effective applications of such data in the design and execution of clothing, equipment, and workspaces in a wide variety of fields. Subjects



covered in Volume I include physical changes in the zero-G environment, variability in body size, mass distribution properties of the human body, arm and leg reach, joint motion, strength, sizing, design of clothing and workspaces, and statistical guidelines. Material presented includes such unpublished anthropometric data measured under one-G and zero-G conditions. In addition, 1985 body size projections and actual cutouts of quarter-scale two-dimensional manikins are given for use by designers.

172. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
NASA Ref. Pub. 1024 July 1978 N79-13711	Anthropometric Source Book Volume II: A Handbook of Anthropometry	Churchill, E., J.T. McConville, L.L. Laubach, T. Churchill, P. Erskine & K. Downing

Abstract: Volume II of this three-volume publication is primarily a handbook of tabulated dimensional anthropometric data. These data resulted from anthropometric surveys of 61 military and civilian populations of both sexes from the United States, Europe, and Asia. Some 295 measured variables are defined and illustrated. Volume II is probably the most comprehensive source of summarized body-size data currently in existence.

173. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
NASA Ref. Pub. 1024 July 1978 N79-13712	Anthropometric Source Book Volume III: Annotated Bibliography of Anthropometry	Laubach, L.L., J.T. McConville & I. Tebbetts

Abstract: Volume III lists 236 annotated references related to the field of anthropometry. Every anthropometric survey outlined in Volume II is referenced, as well as a variety of other works on static and working anthropometry of U.S. and foreign populations, anthropometry of parts of the body related to the design of specific items such as gloves or helmets, joint range and arm reach, mass distribution properties of the body, strength data of various kinds, sizing systems, material on zero gravity, and some general reference works.

174. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape September 1978 AD A063 682	The AMRL Anthropometric Data Book Library: Volume V -- U.S. Correlations	N/A

Abstract: Correlation matrices based on data from USAF anthropometric surveys of women (1968, 127 variables), flying personnel (1950, 128 variables; 1967, 190 variables), and basic trainees (1965, 161 variables); a U.S. Army survey

of women searates (1946, 60 variables), the Health Examination Survey of civilian adults (1960-1962, 18 variables), and a survey of law enforcement officers (1974, 23 measurements) are presented for use by engineers who need them in solving design problems and for anthropologists and statisticians whose analyses and understanding of the interrelationships of body size data depend significantly on these coefficients. Sample sizes in these surveys ranged from almost 2000 upward. Sample means and standard deviations are presented for all variables involved. The contents of this tape are also described in the report, Intercorrelations of Anthropometric Measurements: A Source Book for USA Data, Churchill, E., P. Kikta, and T. Churchill, AMRL-TR-77-2 (AD A058 618), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, May 1978. Complete data from the four USAF surveys are described in The AMRL Anthropometric Data Bank Library: Volumes I-V, by Churchill, E., P. Kikta, and T. Churchill, AMRL-TR-77-1 (AD A047 314), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, October 1977, and on magnetic computer tapes available from NTIS. AD numbers for these tapes are: (1968) AD A056 154/AS, (1967) AD A056 155/AS, (1965) AD A056 156/AS, and (1950) AD A056 157/AS.

175, REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-79-2 January 1979 AD A065 901	Guidelines for Fit Testing and Evaluation of USAF Personal Protective Clothing and Equipment	McConville, J.T., I. Tebbetts & M. Alexander

Abstract: Detailed procedures for the conduct of anthropometric fit tests are outlined in this document which is designed primarily for the use of engineering anthropologists and other technical personnel called upon to carry out fit tests and evaluations of personal-protective clothing and equipment. Suggestions are provided for the design of questionnaires, the selection of a representative test sample, and the choice of dimensions to be measured. The authors outline step-by-step procedures for conducting the fit test itself and discuss various features on the test item which will require evaluation. These include protective capacity, fit, function, comfort, and integration with other parts of an assemblage.

Recommendations for reporting significant results and suggested guidelines for approval or rejection of the test item are given in the concluding chapter. An appendix includes sample forms and supporting materials which are recommended for use by the investigator.

176. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
ADTC-TR-79-5 January 1979	DT&E of Aerial Stores Lift Truck (ASLT) A/S 32K-8	Atkinson, F.B.

Abstract: This test was conducted to perform Development Test and Evaluation (DT&E) on the Aerial Stores Lift Truck (ASLT) A/S 32K-8. The ASLT is a four-wheeled, self-propelled, hydraulically operated lift and positioning

device. Remote control for positioning functions is also included in the vehicle design in the form of a hand-held remote control unit (RCU). Test objectives were to verify physical and general performance characteristics of the ASLT; investigate the effects of selected MIL-STD-810C environmental tests; and verify ASLT interface with selected munitions, munitions handling equipment, and aircraft. The ASLT successfully met most physical and general performance requirements. It also completed MIL-STD-810C high temperature, low temperature, and dust environmental testing. The ASLT performed munitions loadings on the B-52D, B-52H, and FB-111 aircraft. No problems with aircraft/ASLT interfaces were noted. The detailed human factors evaluation points out several areas which would enhance the operation and maintenance of the vehicle. Maintenance on the ASLT is viewed as a problem area due to the limited access provided and the complexity of the system. Limited evaluations of safety and the adequacy of vehicle operational and maintenance literature were performed.

177. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-79-28 April 1979 AD A070 732	Revised Height/Weight Sizing Programs for Men's Protective Flight Garments	Alexander, M., J.T. McConville & I. Tebbetts

Abstract: Presented in this report is an updated series of height/weight sizing programs for use by designers of protective clothing for USAF men. The sizing values are based on an analysis of data obtained in the 1967 survey of flying personnel and cover some 71 dimensions (excluding head, hand, and foot measurements).

Sizing tables containing specific data from which design values can be obtained are given for four-, six-, eight-, and twelve-size programs. Accompanying these working data are: bivariate tables which graphically illustrate how the sizing programs were derived; summary statistics and selected percentile data for each variable; and tariffs suggesting the number of garments to be procured for each size.

Supporting tests, designed to give the reader some background and guidance in the use of this material, include a step-by-step explanation of how sizing programs are developed, an explanation of statistical terms and procedures, and some guidelines for selection of the sizing program appropriate for a given garment.

This report is designed to update an earlier series of height/weight programs based on a flying population surveyed in 1950. Height/weight programs for women fliers are contained in a companion document, Height/Weight Sizing Programs for Women's Protective Garments, I. Tebbetts, J.T. McConville, and M. Alexander, AMRL-TR-79-35 (AD A072 376), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, June 1979.



178. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-79-33 June 1979 AD A072 353	Design Criteria for Characterizing Individuals in the Extreme Upper and Lower Body Size Ranges	Robinette, K.M. & T. Churchill

Abstract: Designers commonly attempt to represent a range of human body sizes by using human manikins, three-dimensional forms, computer simulations, and various other models. These analogues are developed from a limited number of body size groupings, often utilizing 5th, 50th, or 95th percentile values. There are serious limitations to this percentile approach, exemplified by the fact that at the ends of the distribution, percentile values are not additive. Focusing on the ends of the distribution, where limitations are most intense, this report pinpoints and illustrates problems associated with the use of the percentile values, and describes two alternative approaches: subgroup and regression values. Either of these alternatives offers significant improvement over the percentile approach and can be used to characterize any portion of the body size distribution. Regression equations for predicting dimensions from weight and stature and from weight and sitting height are provided to aid designers in computing dimensional body size data needed for cockpit and other workstation layouts.

179. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-79-35 June 1979 AD A072 376	Height/Weight Sizing Programs for Women's Protective Garments	Tebbetts, I., J.T. McConville & M. Alexander

Abstract: Presented in this report is a series of height/weight sizing programs for use by designers of protective clothing for USAF women. The sizing values are based on an analysis of data obtained in the 1968 survey of Air Force women and cover some 60 dimensions (excluding head, hand, and foot measurements).

Sizing tables containing specific data from which design values can be obtained are given for four-, six-, eight-, and twelve-size programs devised to accommodate the USAF women's population as a whole. In addition, the authors present a four-size system designed specifically for a women's flying population and based on data obtained from a subgroup of the 1968 sample composed of individuals who meet the height and weight requirements for USAF aircrew. Accompanying these working data are: bivariate tables which graphically illustrate how the sizing programs were developed; summary statistics and selected percentile data for each variable; and tariffs suggesting the number of garments to be procured for each size.

Supporting tests, designed to give the reader some background and guidance in the use of this material, include a step-by-step explanation of how sizing programs are developed, an explanation of statistical terms and procedures, and some guidelines for selection of the sizing program appropriate for a given garment.

Updated height/weight programs for USAF aircrewmembers can be found in a companion document entitled Height/Weight Sizing Programs for Men's Protective Flight Garments, by M. Alexander, J.T. McConville, and I. Tebbetts, AMRL-TR-79-28 (AD A070 732), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, April 1979.

180. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-79-42 May 1977 AD A069 195	The Aerospace Medical Research Laboratory's Anthropometric Data Bank: A Resource for Designers	McConville, J.T., E. Churchill & C.E. Clauser

Source: Preprints of the 1977 Scientific Program, Aerospace Medical Association, May 1977.

Abstract: The Aerospace Medical Research Laboratory has established and maintains an anthropometric data bank incorporating at a single center raw data from many large-scale anthropometric surveys. The bank contains data from 30 such surveys and represents a total sample of more than 80,000 subjects. These subjects represent United States and foreign military personnel, men and women, and though less extensive, United States civilian men and women. The data are on magnetic tapes in comparable format so that they can be recalled and reanalyzed as necessary.

181. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-79-44 August 1979 AD A074 723	Anthropometric Sizing, Fit- Testing and Evaluation of the MBU-12/P Oral-Nasal Oxygen Mask	Alexander, M., J.T. McConville, & I. Tebbetts

Abstract: This report describes the anthropometric sizing procedures used in the development of the MBU-12/P oral-nasal oxygen mask and documents results of subsequent fit-testing and evaluation of the mask. A successor to the MBU-5/P, the MBU-12/P is designed to withstand the G and Q forces in the newer high performance aircraft as well as to provide a better fit and improved visibility.

Sizing analysis and fit-testing revealed that four sizes of the MBU-12/P are sufficient to cover the USAF male flying population; the anthropometry and statistics upon which this decision was based are described in this report. Also documented here are the results of a number of ground and flight tests conducted over a period of four years which provide both objective and subjective evidence that the MBU-12/P is a well fitting mask which successfully achieves its design objectives. Subjects of all the tests were experienced aircrew whose head and face measurements were representative of a full range of the USAF flight crew population. Results of all the fit test/evaluations revealed a high degree of user acceptance and a decided preference for the MBU-12/P when compared to the older MBU-5/P.

182. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AMRL-TR-79-69 July 1979 AD A074 807	A Comparison of Male and Female Body Sizes and Proportions	Robinette, K.M. T. Churchill & J.T. McConville

Abstract: There has been, in the past few years, an increase in the diversity of occupational positions filled by women in the Air Force and the other military branches. As the opportunities increase, the workplace designer is faced more and more frequently with the problem of accommodating the female. Accompanying this problem is a need for documentation of the true differences in body size proportions between Air Force men and women. This report is an initial attempt at fulfilling this need.

Utilizing the 1977 Army survey, because it is the only survey in which both military males and females were measured at the same time and place, by the same measurers, and using the same measuring techniques and instruments, this study investigates two basic assumptions about the relationship between male and female body size and proportions. The results of these investigations serve to pinpoint where differences occur and the magnitude of those differences. This should aid in determining the designs or changes in designs which will be necessary to accommodate the female.

183. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-80-64 1979 AD A087 619	Factor Analysis of Anthropometric Data for Fifteen Race-Age-National Origin Specific Groups	Churchill, E., D. Robinow & P. Erskine

Source: Physiological and Morphological Adaptation and Evaluation, W.A. Stini, Editor, Mouton, New York, 1979.

Abstract: An investigation of factor analysis of anthropometric data was conducted to determine its usefulness in comparative studies. Some 40 anthropometric variables were selected for use and an analysis carried out on 15 samples drawn from the Aerospace Medical Research Laboratory's Anthropometric Data Bank. To ascertain the consistency of factor analysis results when obtained from essentially identical data, an initial study was carried out by running factor analyses on ten groups of 400 men selected, without duplication, from a particular survey sample.

184. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-80-119 December 1980 AD A097 238	Anthropometric Relationships of Body and Body Segment Moments of Inertia	McConville, J.T., T.D. Churchill, I. Kaleps, C.E. Clauser & J. Cuzzi



Abstract: This report documents the results of a study aimed at demonstrating that mass distribution properties of the human body and its segments can be predicted from anthropometric dimensions. Investigators combined stereo-photometric and anthropometric techniques to measure 31 male subjects. Bodies were photographically segmented into 24 parts and their volume, center of volume, and principal moments of inertia established stereometrically. Principal moments were measured about three principal axes of inertia which were established with reference to anatomical axis systems based on easily located body landmarks.

Seventy-five body size variables were measured anthropometrically and an additional 10 dimensions were derived from the measured variables. Multiple regression equations were devised for the total body and for each segment using the most highly correlated variables on each segment, and stature and weight for determining volume and principal moments of inertia.

Included is a brief review of the literature with emphasis on earlier studies by authors which provide the rationale for the reliability of the stereo-photometric method in determining mass distribution properties of living subjects. The data analysis section provides tables illustrating each of the segments and its axis systems, the segmental data established in this study, and a series of regression equations estimating volume and principal moments from anthropometric measurements.

185. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-80-124 October 1980	Designer's Guide for the Panel Program	Korna, M. & N. Aume

Abstract: This Designer's Guide describes an interactive computer graphics program intended for the computer-aided design of avionics control and display panels. Using this program, a designer can specify the basic panel on which all other components will be mounted as well as the components themselves. Also, he can locate and relocate the components, add graphic elements (text, lines, circles), and call for printed, punched, or hard copy (plot) output. The requirements and considerations of several applicable MIL-Standards have been incorporated into the program to facilitate the design process.

The Guide to the operation of the Panel program includes descriptions of the processing available for each of the program functions and subfunctions. A listing of the program is also included along with a brief description of most of the subroutines.

186. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape May 1980 AD A086 301	The AFAMRL Anthropometric Data Bank Library: Volume VI--The 1946 Survey of Army Female Separatees	N/A

Abstract: The 1946 Survey of Army Female Separates was conducted at the end of World War II at the separation census on 3614 nurses, 4445 enlisted WACs, and 484 WAC commissioned officers. Publications referring to this survey are: (1) Reference Anthropometry of Army Women by F. Randall and E. Munro, Environmental Protection Section, Report No. 149, Quartermaster Climatic Research Laboratory, Lawrence, Massachusetts, 31 March 1949; (2) Applications of Anthropometry to the Determination of Size in Clothing by F. Randall, Environmental Protection Series Report No. 133, Quartermaster Climatic Research Laboratory, Lawrence, Massachusetts, June 1948; (3) Survey of Body Size of Army Personnel, Male and Female: Phase 4, Body Dimensions of Army Females by F. Randall, Environmental Protection Section, Climatic Research Laboratory, Lawrence, Massachusetts. Punched cards containing the raw data were supplied to AFAMRL in 1972 by Robert White of the U.S. Army Natick Research and Development Command, Natick, Massachusetts.

187. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape May 1980 AD A086 305	The AFAMRL Anthropometric Data Bank Library: Volume VII--The 1966 Survey of Army Personnel	N/A

Abstract: The 1966 Survey of Army Personnel was sponsored by the Defense Supply Agency and conducted in late 1965 and early 1966 by the U.S. Army Natick Laboratories, Natick, Massachusetts, and the U.S. Army General Test Activity. The survey was directed by Mr. Robert White of Natick Laboratories, and data editing and analysis were done by Edmund Churchill of the Anthropology Research Project, then at Antioch College, under contract to the Air Force. This survey is thoroughly documented in TR-72-51-CE, The Body Size of Soldiers, by White and Churchill, December 1971 (AD 743 465).

188. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape May 1980 AD A086 304	The AFAMRL Anthropometric Data Bank Library: Volume VIII--1970 Survey of Army Aviators	N/A

Abstract: An anthropometric survey of U.S. Army Aviators was conducted at Fort Rucker, Alabama in 1970. Data for 85 body measurements and for several variables describing the socio-military background of the survey subjects were gathered on a sample of 1482 flight personnel.

The sample consisted of 388 enlisted men, 259 Warrant Officers, 410 rated pilots (warrant), 186 commissioned trainees, and 234 rated pilots (commissioned). Complete details and the results are published in the report Anthropometry of U.S. Army Aviators, 1970, by Churchill, McConville, Laubach, and White, TR-72-52-CE, Clothing and Personal Life Support Equipment Laboratory, U.S. Army Natick Laboratories, Natick, Massachusetts, 1971 (AD 743 528).

189. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape May 1980 AD A086 302	The AFAMRL Anthropometric Data Bank Library: Volume IX--1977 Survey of U.S. Army Women	N/A

Abstract: The 1977 Survey of U.S. Army Women was conducted at four Army bases during the winter of 1976-1977. The survey was carried out and a series of reports prepared by the Anthropology Research Project under contract with the U.S. Army Research and Development Command, Natick, Massachusetts. Data for 69 body size measurements were obtained on a sample of 1331 women (Subject No. 92 has been deleted from this tape because of extreme obesity) who covered a wide range of age, rank, and military assignments. Additional data were obtained on four subgroups of between 200 and 300 women for (1) other standard body measurements, (2) workspace measurements, (3) head and face measurements, and (4) static strength measurements. A small sample of male subjects (287) were measured for an abbreviated set of measurements at the end of the female survey to provide comparative data. The results of this survey were published in five reports:

1. Anthropometry of Women of the U.S. Army - 1977, Report No. 1, Methodology and Survey Plan, Laubach et al., Natick/TR-77/021 (AD A043 715), June 1977.
2. Anthropometry of Women of the U.S. Army - 1977, Report No. 2, The Basic Univariate Statistics, Churchill, E. et al., Natick/TR-77/024 (AD A044 806), June 1977.
3. Anthropometry of Women of the U.S. Army - 1977, Report No. 3, Bivariate Frequency Tables, Churchill, T. et al., Natick/TR-77/028 (AD A046 692), July 1977.
4. Anthropometry of Women of the U.S. Army - 1977, Report No. 4, Correlation Coefficients, Tebbetts, I. et al., Natick/TR-80/016 (AD A084 119), February 1980.
5. Anthropometry of Women of the U.S. Army - 1977, Report No. 5, Comparable Data for U.S. Army Men, McConville et al., Natick/TR-77/029 (AD A048 591), July 1977.

This tape is divided into ten files:

1. File No. 1 has the index and background information.
2. File No. 2 has the core group of 69 measurements plus 10 background variables for 1330 subjects.
3. File No. 3 has 28 standard body size measurements measured on 255 subjects. Stature and weight from the core group of measurements have been included for each subject.
4. File No. 4 has 14 workspace measurements plus stature and weight from the core group of measurements for 300 subjects.



5. File No. 5 has 31 head and face measurements plus head circumference, head length, and head breadth from the core group of measurements for 216 subjects; ear length, ear breadth, and binauricular breadth were also measured on 37 subjects.
6. File No. 6 has 36 static strength measurements plus stature and weight from the core group of measurements for 349 subjects.
7. File No. 7 has 44 measurements from the core group and 14 measurements from the standard body size subgroup plus eight background variables for 287 Army men.
8. File No. 8 has 14 workspace measurements plus stature and weight from the core group of measurements for 106 Army men.
9. File No. 9 has 34 head and face measurements plus head circumference, head length, and head breadth from the core group of measurements for 102 Army men.
10. File No. 10 has 36 static strength measurements plus stature and weight from the core group of measurements for 102 Army men.

190. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
Computer Tape May 1980 AD A086 303	The AFAMRL Anthropometric Data Bank Library: Volume X--U.S. Army Correlations	N/A

Abstract: The AFAMRL Anthropometric Data Bank Library, Volume X, U.S. Army Correlations, contains correlation coefficients for the surveys found in Volumes VI-IX. It is divided into nine files as follows:

File 1/Table of Contents		
File 2/1946 Army Female Separates	NV=65	NS=1791
File 3/1966 Army Personnel	NV=75	NS=6646
File 4/1970 Army Aviation	NV=88	NS=1482
File 5/1977 Army Women-Core Anthropometry	NV=70	NS=1330
File 6/1977 Army Women-Core & Traditional Anthropometry	NV=98	NS=255
File 7/1977 Army Women-Core & Workspace	NV=84	NS=296
File 8/1977 Army Women-Head & Face	NV=37	NS=215
File 9/1977 Army Women-Core & Static Strength	NV=88	NS=344

(Where NV is the number of variables for that file and NS is the number of subjects.)

The surveys used in this volume are referenced in the following publications:

Reference Anthropometry of Army Women, F. Randall and E. Munro, Environmental Protection Section, Report No. 149, Quartermaster Climatic Research Laboratory, Lawrence, Massachusetts, 31 March 1949 (AD 209 837).

Application of Anthropometry to the Determination of Size in Clothing, F. Randall, Environmental Protection Series Report No. 133, Quartermaster Climatic Research Laboratory, Lawrence, Massachusetts, June 1948 (AD 125 573).

Survey of Body Size of Army Personnel, Male and Female: Phase 4, Body Dimensions of Army Females, F. Randall, Environmental Protection Series Report No. 123, July 1947, Climatic Research Laboratory, Lawrence, Massachusetts (AD 209 809).

The Body Size of Soldiers, White and Churchill, TR-72-51-CE, U.S. Army Natick Laboratories, Natick, Massachusetts, December 1971 (AD 743 465).

Anthropometry of U.S. Army Aviators, 1970, Churchill, McConville, Laubach and White, TR-72-52-CE, Clothing and Personal Life Support Equipment Laboratory, U.S. Army Natick Laboratories, Natick, Massachusetts, 1971 (AD 743 528).

Anthropometry of Women of the U.S. Army--1977, which was published in four reports: Report No. 1, Methodology and Survey Plan, Laubach et al., Natick/TR-77/021 (AD A043 715), June 1977; Report No. 2, The Basic Univariate Statistics, Churchill, E., et al., Natick/TR-77/024 (AD A044 806), June 1977; Report No. 3, Bivariate Frequency Tables, Churchill, T., et al., Natick/TR-77/028 (AD A046 692), July 1977; Report No. 4, Correlation Coefficients, Tebbetts, I. et al., Natick/TR-80/016 (AD A084 119), February 1980; and Report No. 5, Comparable Data for U.S. Army Men, McConville et al., Natick/TR-77/029 (AD A048 591), July 1977.

191. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
July 1980	Workspace Evaluation and Design: USAF Drawing Board Manikins and the Development of Cockpit Geometry Design Guides	Kennedy, K.W.

Source: Anthropometry and Biomechanics, Theory and Applications, R. Easterby, K.H.E. Kroemer, and D.G. Chaffin, Editors, pp. 205-213, Plenum Press, New York, 1982. Also presented at the NATO Symposium on Anthropometry and Biomechanics, Theory and Application, Cambridge, England, July 1980.

Abstract: Since World War II, there has been a steady increase in the use of anthropometric data in the design and evaluation of aircraft cockpits. Paralleling this trend, and largely responsible for it, has been a corresponding increase in the complexity of the aircraft themselves. A number of techniques have been used to render anthropometric data more useful to the crewstation designer. One of the more recent techniques is the USAF Two-Dimensional Drawing Board Manikins. This paper describes these manikins and the manner in which they are employed for the development of Cockpit Geometry Design Guides.

192. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
July 1980	An Anthropometric Data Bank, Its Hidden Dimensions	McConville, J.T. & C.E. Clauser

Source: Anthropometry and Biomechanics, Theory and Applications, R. Easterby, K.H.E. Kroemer, and D.B. Chaffin, Editors, pp. 35-42, Plenum Press, New York, 1982. Also presented at the NATO Symposium on Anthropometry and Biomechanics, Theory and Applications, Cambridge, England, July 1980.

Abstract: The goal of an anthropometric data bank is to aid in the reuse of data for many different applications. However, the data themselves are merely the substance being molded into the form desired. There are numerous supporting programs and procedures which constitute the functional components of a bank. This report presents and discusses some of these often unseen but integral aspects using examples drawn from the AFAMRL anthropometric data bank. Among the items discussed are editing programs, programs for regrouping data, and programs for graphic displays.

193. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
July 1980	Biomechanical Computer Modeling for the Design and Evaluation of Work Stations	McDaniel, J.W.

Source: Anthropometry and Biomechanics, Theory and Applications, R. Easterby, K.H.E. Kroemer, and D.B. Chaffin, Editors, pp. 91-95, Plenum Press, New York, 1982. Also presented at the NATO Symposium on Anthropometry and Biomechanics, Theory and Applications, Cambridge, England, July 1980.

Abstract: Biomechanical computer models have application to many workplace design problems including: physical size accommodation, visual field accommodation, reach accommodation, dynamic response to acceleration, and strength assessment. In this paper, these applications are discussed along with some of the problems associated with such modeling. Currently, one major problem is the inadequacy of the available data bases. The majority of the data available was not gathered for the purpose of computer modeling. Consequently, much of it is not directly applicable. Studies, in progress, for the purpose of satisfying this need are described. The COMBIMAN (COMputerized BIomechanical MAN-model) is cited as an example of a computer-generated mock-up of an aircraft cockpit, or other seated workplace.

194. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
July 1980	The Human Machine in Three Dimensions, Implications for Measurement and Analysis	Reynolds, H.M.

Source: Anthropometry and Biomechanics, Theory and Applications, R. Easterby, K.H.E. Kroemer, and D.B. Chaffin, Editors, pp. 25-34, Plenum Press, New York,



1982. Also presented at the NATO Symposium on Anthropometry and Biomechanics, Theory and Application, Cambridge, England, July 1980.

Abstract: The human body has been compared to a machine for both figurative as well as analytical purposes. For the present paper, the latter view and the implications for both data collection and data analysis will be examined relative to research conducted in the Systems Anthropometry Laboratory at Michigan State University. This discussion will incorporate data obtained from three-dimensional measurements of the living body, osteological material, and kinematic research using unembalmed cadavers. The purpose of the paper is to discuss the empirical study of the three-dimensional description of human body position and mobility.

195, REPORT NUMBER/DATE	TITLE	AUTHOR(S)
December 1980	Three-Dimensional Kinematics in the Pelvic Girdle	Reynolds, H.M.

Source: Journal of American Osteopathic Association, 80:4, December 1980.

Abstract: Relative motion of the bones in the pelvis has been under investigation for many years. This paper reviews the literature and introduces new three-dimensional data describing motion of the sacrum relative to the innominate bone for different positions of the femur in three-dimensional space. These data were obtained in the Systems Anthropometry Laboratory at Michigan State University, East Lansing, using an unembalmed adult male.

Stereoradiography was used to measure the location of landmarks on the sacrum, innominate bone, and femur with the thigh in "neutral" erect, maximum flexion, abduction, and abductoflexion positions. The data have been analyzed by screw axis analysis, which characterizes three-dimensional movement in terms of a rotation angle, a translation, and three direction cosines of a vector defining the direction of the screw axis. These preliminary results suggest that the pelvis cannot be considered a rigid body and that it serves as the site at which loads and motions are transferred from the trunk to the lower limb.

196. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1980	Anatomical Frames of Reference and Biomechanics	Reynolds, H.M. & R.P. Hubbard

Source: Human Factors, 22:2, 171-176, 1980.

Abstract: For dynamic simulation of human movement, segment axis systems are often defined by the inertial tensor unique to each simulated body segment. When empirical three-dimensional data are sought that describe either the mass distribution or the kinematic properties of the human body, anatomical frames of reference are needed for the sake of measurement methodology and data comparability. Anatomical axis systems are based on anatomical landmarks that

must represent functional and stable features in the skeletal geometry. The role of anthropometric landmarks used in defining anatomical coordinate axis systems is discussed with examples from current research regarding the kinematics of the hip joint and mass distribution of the whole body. The use of anatomical frames of reference will improve the correspondence between computer simulations of the human body and the biological structure.

197. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-81-39 1981 AD A098 256	Male and Female Strength Capabilities for Operating Aircraft Controls	McDaniel, J.W.

Abstract: There has long been concern that the resistance of some aircraft controls is too large. Now that the Air Force has both male and female pilots, that concern is greater. The Workload and Ergonomics Branch of AFAMRL has just completed a study of the physical strength and endurance capabilities of 61 male and 61 female subjects in a stick-controlled aircraft simulator. Additionally, 110 of these subjects completed a nine-week exercise training program to strengthen muscles used on aircraft controls. Results show weak males and weak females have similar leg strength. The arm strength of strong females was similar to that of weak males, however. Physical training improved leg strength more than arm strength. Males and females had similar increases in strength due to physical training. Most of the females and some males fell below the resistance specification for current aircraft.

198. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-81-151 April 1982	User's Guide for COMBIMAN Programs (COMputerized Biomechanical MAN-model), Version 5	Bapu, P., P. Kikta, M. Korna & J. McDaniel

Abstract: This User's Guide describes the procedures to operate the Air Force Aerospace Medical Research Laboratory's (AFAMRL) COMputerized BIomechanical MAN-model (COMBIMAN) programs. The guide is based on the programs as of 1 May 1981. The guide includes an introduction to the man-model and the conventions used to develop and analyze crewstation configurations. It also deals with the operations of the programs included in the COMBIMAN system.

These programs include the interactive graphics program CBM05, and the three key file creation/modification programs CBMAN, CBMCM, and CBMVM, which create and maintain the data bases of anthropometric surveys, crewstation configurations, and visibility contour definitions, respectively. The guide also contains a complete description of the use of CBMOFF, the off-line plot program.

The guide to operate the four main programs includes descriptions of the available processing for each program, definitions and examples of all input

and output data formats, procedures to load the programs, and explanations of all diagnostic messages generated by the programs.

199. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-81-152 April 1982	The Visibility Analysis Program User's Guide	Kikta, P., M. Korna & J. Moy

Abstract: This Visibility Analysis Program User's Guide describes a computer program that generates a hard copy plot of the visual angles to crewstation components from the crewmember viewpoint. Using this program, crewstation designers can evaluate crewmember/crewstation visual interaction.

The guide also describes a procedure to facilitate installation and use of the program at the user's facility. The procedure consists of three principal steps: installation of the program on user's computer system, digitization of crewstations, and program execution. A listing of the program is also included.

200. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
SAE Tech. Paper No. 810217 February 1981	An Alternative to Percentile Models	Robinette, K.M. & J.T. McConville

Source: SAE Transactions, pp. 938-946, 1982. Also presented at the Society of Automotive Engineers International Congress and Exposition, Detroit, Michigan, February 1981.

Abstract: Percentile values are valuable statistics for representing the extreme ends of a distribution of sizes for a single human body dimension; however, their use is not suitable to every problem. When it is desirable to combine dimensions in order to construct a model of the human body or any of its parts, percentiles can create problems due to the fact that, with the exception of 50th percentiles, percentile values are not additive. This report demonstrates the seriousness of the problems associated with the use of percentiles, and describes and compares an alternative approach for representing human body size variability. This alternative, which utilizes regression equations, offers a solution which is easily accessible and demonstrably an improvement over percentiles for the purpose of creating human models.

201. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1982	Systems Anthropometry: Development of a Stereoradiographic Measurement System	Reynolds, H.M., R.C. Mallgren & J. Marcus



Source: Journal of Biomechanics, 15:4, 1982.

Abstract: A three-dimensional measurement system using stereoradiography and anatomical landmarks is described. Two sets of radiographic targets are employed to obtain a three-dimensional description of the position and mobility of the human body.

202. <u>REPORT NUMBER/DATE</u>	<u>TITLE</u>	<u>AUTHOR(S)</u>
AFAMRL-TR-83-001 January 1983	Weight Lift Capabilities of Air Force Basic Trainees	McDaniel, J.W., R.J. Skandis & S.W. Madole

Abstract: To establish physical strength and endurance criteria for assigning personnel to jobs with a heavy physical demand, weight lifting and holding tests were performed on Air Force basic trainees. Maximum weight lift capability was measured on 1066 male and 605 female basic trainees at Lackland Air Force Base. In the Incremental Weight Lift Test, subjects raised the handles of a weight lift machine to a height of 6 feet or more above the floor. The initial weight of 40 pounds was increased by 10-pound increments until the subjects were unable to raise the weight to 6 feet. Maximum weight lift capability to elbow height was then measured as a continuation of this Incremental Weight Lift Test. The male basic trainees averaged 114.1 pounds on the Incremental Lift to 6 feet (S.D. = 23.18), while the female basic trainees averaged 56.9 pounds to 6 feet (S.D. = 11.75). The male basic trainees averaged 129.1 pounds (S.D. = 24.60) to elbow height, while the females averaged 67.7 pounds (S.D. = 13.91).

An endurance test measured the duration of holding a 70-pound weight at elbow height. Maximum weight holding endurance was measured on 1066 male and 573 female basic trainees. Male basic trainees held the weight an average of 53.3 seconds (S.D. = 22.11), while the females averaged 10.3 seconds (S.D. = 10.5).

In comparing the body size distributions of these 2132 male and 1178 female basic trainees with previous anthropometric surveys from 1965 to 1968, it was found that there was a significant increase in stature and weight for both males and females.

These and other tests by the Air Force demonstrate a safe methodology for performing weight lift testing. Weight lift testing is valuable as a personnel screening and assignment because it is highly correlated with the types of dynamic lifting in manual materials handling activities.

203. <u>REPORT NUMBER/DATE</u>	<u>TITLE</u>	<u>AUTHOR(S)</u>
AFAMRL-TR-83-016 February 1983	A Foundation for Systems Anthropometry: Lumbar/ Pelvic Kinematics	Reynolds, H.M. & S. Leung

Abstract: Research protocol and results from System Anthropometry Laboratory's three-dimensional investigation of the lumbar/pelvic linkage system are presented. A stereoradiographic system measures three-dimensional coordinates of implanted targets in the skeletal system of an unembalmed cadaver seated in a wooden seat conforming to Air Force specifications. The cadaver is experimentally positioned to obtain three-dimensional data on lumbar extension, flexion, and lateral sidebending motions. Data are analyzed to provide a screw axis description of the instantaneous axis of rotation for each change of position.

In addition, position vectors are calculated that describe locations of the bones in the lumbar/pelvic linkage system and a point on the screw axis closest to the origin of the bone frame of reference. The data are presented in three-dimensional coordinates measured in a laboratory with a spatial accuracy of approximately  $\pm 0.03$  cm. The extensive references to measurement and measurement techniques studies offer a listing not presented elsewhere in the literature, or in other reviews of the literature, and with particular application to systems anthropometry, from the fields of anthropometry, osteology, kinematics, and three-dimensional measurement techniques.

204. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-83-081 October 1983	Human Strength Capabilities for the Operation of Parachute Ripcords and Riser Releases	Aume, N.M., J. McDaniel & T. Garver

Abstract: Military Specification MIL-P-6645H permits a maximum pull of 27 pounds to activate a parachute ripcord. A test was conducted to evaluate this force. Two hundred eleven physically fit male and female subjects made maximum voluntary exertions on five different parachute ripcord handles with the left hand, the right hand, and with both hands. The applied isometric forces were recorded. Considerable differences in the recorded forces were found to be attributable to sex and to one- versus two-hand pulls; lesser differences were caused by variations in ripcord handle types and locations. When both hands were used, almost all male subjects could exceed the permitted 27-pound pull. Significant numbers of female subjects using either one or both hands, and male subjects using only one hand, could not exceed 27 pounds of pull. As a result, the authors recommend that the currently specified 27-pound limit not be increased as has been proposed, and that teaching the two-hand pull be continued. The same subjects also performed maximum voluntary exertions on two types of riser releases with the left and right hands. The type of riser release caused a significant difference in the force exerted.

205. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-83-097 December 1983 Version 5	User's Guide for COMBIMAN Programs (COMputerized BIomechanical MAN-Model)	Bapu, P., M. Korna & J. McDaniel

Abstract: This User's Guide describes the procedures to operate the Air Force Aerospace Medical Research Laboratory's (AFAMRL) COMputerized BIomechanical MAN-model (COMBIMAN) programs. The Guide is based on programs as of 1 May 1981. The Guide includes an introduction to the man-model and conventions used to develop and analyze crew station configurations. It also deals with the operations of the programs included in the COMBIMAN system. These programs include the interactive graphics program CBMO6, and the three key data base creation/modification programs CBMAM, CBMCM, and CBMVM, which create and maintain the data bases of anthropometric surveys, crew station configurations, and visibility contour definitions, respectively. The guide also contains a complete description of the use of CBMOFF, the off-line plot program.

The guide to operate the four main programs includes descriptions of the processing capabilities for each program, definitions and examples of all input and output data formats, procedures to execute the programs, and explanations of all diagnostic messages generated by the programs.

206. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
FAA-AM-83-16 September 1983 Revised Edition	Anthropometric and Mass Distribution Characteristics of the Adult Female	Young, J.W., R.F. Chandler, C.C. Snow, K.M. Robinette, G.F. Zehner & M.S. Lofberg

Abstract: This study of 46 living adult females is part of a long-range research program designed to establish valid analytical relationships between readily measured body dimensions and mass distribution characteristics of living populations. Presented in this report are data describing the mass distribution characteristics of primary and composite body segments. The report also contains sets of regression equations which can be used to predict segmental volumes and moments of inertia from anthropometric data. The data base is derived from both classical anthropometric measurements and from stereophotogrammetric techniques. Subjects were representative of a general United States population as defined by the 1971-74 Public Health Service, Health and Nutrition Examination Survey (HANES). The data obtained describe segment and segment composite volumes, centers of volume, intersegment cut centroids, principal inertial axes, and surface anatomical landmarks with respect to anatomical axes developed for each segment. Experiments designed to test the validity of research techniques and controls, and to measure the



differences between stereophotometrically derived values and values obtained by direct measurement techniques are also described here.

It is anticipated that these data will be useful as design criteria for anthropomorphic test devices used in safety research, design and performance evaluation of safety restraint systems, and development of body prostheses.

207. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-84-040 August 1984	A Machine for Weight-Lift Testing	Aume, N.M.

Abstract: This report describes the design and building details of a weight lifting machine which is primarily intended for Factor X testing where only occasional use is foreseen and an expensive machine would not be cost effective. The machine allows one to select, in 10-pound increments, a weight from 40 to 200 pounds for lifting. The design of the machine allows the weight to move only up and down, eliminating any unwanted and hazardous motions.

208. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1984	Analytical Relationships Between Body Dimensions and Mass Distribution Characteristics of Living Populations	Zehner, G.F.

Source: Trends in Ergonomics/Human Factors I, A. Mital, Editor, Elsevier Science Publishers B.V. (North Holland), 1984.

Abstract: A study of 77 living adults established that readily measured body dimensions can be used to predict mass distribution characteristics of living populations. The resulting data base, derived from both classical anthropometric measurements and modern stereophotogrammetric techniques, describes the mass distribution characteristics of both primary and composite body segments. It is anticipated that these data will be useful in the design of human analogues used in safety research, design and performance evaluation of safety restraint systems, and development of body prostheses.

209. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AFAMRL-TR-85-057 May 1985 Version 7	User's Guide for COMBIMAN Programs (COMputerized Biomechanical MAN-Model)	Korna, M. & J.W. McDaniel

Abstract: This User's Guide describes the procedures to operate the Air Force Aerospace Medical Research Laboratory's (AFAMRL) Computerized Biomechanical

MAN-model (COMBIMAN) programs. The Guide is based on the programs as of December 1984. The Guide includes an introduction to the man-model and the conventions used to develop and analyze crew station configurations. It also deals with the operations of the programs included in the COMBIMAN system. These programs include the interactive graphics program CBM07 and the three key data base creation/modification programs CBMAM, CBMCM, and CBMVM, which create and maintain the data bases of anthropometric surveys, crew station configurations, and visibility contour definitions, respectively. The guide also contains a complete description of the use of CBMOFF, the off-line plot program. For the convenience of users without an on-line plotting capability, the program CBM07NPL is included in this version to use in place of CBM07.

The guide to operate the four main programs includes descriptions of the processing capabilities for each program, definitions and examples of all input and output data formats, procedures to execute the programs, and explanations of all diagnostic messages generated by the programs.

210. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-85-062 January 1986	A Collation of United States Air Force Anthropometry	Kennedy, K.W.

Abstract: Four major anthropometric surveys of United States Air Force personnel have been conducted since the end of World War II: that of male rated and non-rated flying personnel in 1950, of male recruits, enlisted and non-rated officers in 1965, of male rated officers and cadets in 1967, and of female officers and enlisted in 1968. Only two surveys have been adequately published: those of 1950 and 1968. For the purposes of this collation, four USAF subpopulations have been distinguished: (1) non-rated male officers and enlisted, (2) rated male officers and cadets, (3) non-rated female officers and enlisted personnel, and (4) rated female officers and cadets. The latter is an artificial subset of women taken from the 1968 survey who meet the Air Force body-size criteria for entry into Undergraduate Pilot Training and retention as a rated officer. Dimension titles and descriptions are listed alphabetically and cross referenced such that the user can be quickly directed to the desired or to related body size data. Summary statistics consist of the number of subjects measured, the mean, standard deviation, and the 1st, 5th, 50th, 95th and 99th percentile values for each dimension.

211. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-85-075 December 1985	Computer-Aided Design Models to Support Ergonomics	McDaniel, J. & W.B. Askren

Abstract: This report describes a new computer-aided design (CAD) and evaluation model to simulate an aircraft maintenance worker called "Crew Chief". The model will interface to two or three CAD systems common in the aerospace industry. Crew Chief will generate a 3-D pictorial of either a male or female maintenance worker, accurate in size, clothing, mobility, accessibility

strength, and visual characteristics. The aircraft designer working at the computerized drawing board, can superimpose the Crew Chief on the design and simulate the performance of maintenance activities. With this tool, the designer can verify that a system is maintainable before even a mock-up is constructed. Because of its general-purpose capability, the Crew Chief model will have application to non-aircraft design evaluations.

212. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-86-016 March 1986	The Derivation of Low Profile and Variable Cockpit Geometries to Achieve 1st to 99th Percentile Accommodation	Kennedy, K.W.

Abstract: This study was undertaken to serve three objectives: (1) to derive new cockpit geometries in which the techniques of vertical aircraft ejection seat adjustment move the small pilot toward his/her controls and the large pilot away from them, thus avoiding the incompatibilities associated with adjusting the small pilot up and aft, away from the hand controls, and the large pilot down and forward, toward hand controls; (2) to demonstrate the relative ease with which the engineer can accommodate to the 1st to 99th percentile range of male body sizes within the USAF, including reach capability; and (3) to demonstrate appropriate techniques in using the AAMRL Drawing Board Manikins in the derivation of basic geometries of ejection seats and of cockpits. Design requirements are: (1) vertical seat adjustment should be for the purpose of bringing the pilot's eyes to a 15-degree Down Vision Line; and (2) all pilots within the anthropometric design range should be able to avoid thrusting their knees forward of the Ejection Clearance Line by assuming the correct ejection posture, even though they might have adjusted the seat to a considerably different position than recommended for their body size. Low Profile and Variable Cockpit Geometries are derived in detailed step by step demonstrations.

213. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1986	Cockpit Automation Technology: A Process for Designing Advanced Aircraft Systems	McDaniel, J.W.

Source: Presented at the Ergonomics Society 1986 Conference, University of Durnham, U.K., April 1986.

Abstract: Future aircraft systems will have additional capabilities and the potential for complexity of operation beyond the abilities or needs of the pilot. Current design methodologies are improving, but are lagging far behind in developing new pilot interface concepts necessary to design an effective cockpit. Multifunction controls and multiple displays with different format, coding, and sensor FOV cannot be operated quickly and efficiently by a pilot trying to maintain situation awareness.



The CAT (Cockpit Automation Technology) Program is developing new and standardized methodologies to support the design of future cockpits. CAT is developing a designer's computer-aided tool kit with the basic computer tools to aid the designer. Some computer tools evaluate mission requirements and translate them into design requirements. The Breadboard Cockpit Simulator provides the designer his own versatile simulator for researching new interface concepts. Some tools measure performance, evaluate task load, and assess performance with alternative concepts. Computer-aided Design tools support cockpit layout and geometry. List processing computer tools support the development of artificial intelligent subsystems as part of the design.

214. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-86-021 May 1986 AD A173 545	Dexterity Testing of Chemical Defense Gloves	Robinette, K.M., C. Ervin & G.F. Zehner

Abstract: Four types of chemical defense gloves (12.5 mil Epichlorohydrin/Butyl, 14 mil Epichlorohydrin/Butyl, 14 mil Butyl and 7 mil Butyl with Nomex overgloves) were evaluated for their effect on hand dexterity. Fifteen male and 15 female subjects performed four dexterity tests (O'Connor Finger Dexterity Test, Pennsylvania Bi-Manual Worksample-Assembly, Minnesota Rate of Manipulation Turning, and the Crawford Small Parts Dexterity Test-Screws) bare-handed and while wearing the chemical defense gloves. Results indicated that subjects' performances were most impaired by the 7 mil Butyl with Nomex overglove. Though differences between the other three gloved conditions were not always statistically significant, subjects performed slightly better while wearing the Epichlorohydrin/Butyl gloves, no matter which thickness, than they did while wearing the 14 mil Butyl gloves. High negative correlations between anthropometry and gloved test scores of subjects suggested that poor glove fit may also have affected subjects' performances.

215. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-86-029 July 1986 AD A173 193	A Nine-Size System for Chemical Defense Gloves	Robinette, K.M. & J.F. Annis

Abstract: The purpose of this effort was to meet the need for improved sizing of chemical defense (CD) gloves for Air Force men and women. A nine-size system was developed from available hand data. The development process and size values are presented in this report. Some summary statistics and regression equations are provided to aid investigators who may wish to make modifications.

Although the sizing system outlined in this report is statistically sound, it is experimental. The authors recommend that anthropometric fit-testing be conducted prior to full-scale glove production.

216. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1986	Computer Graphics and Diagnostics	Beecher, R.M.

Source: Proceedings of the Human Factors Society - 30th Annual Meeting - 1986, The Human Factors Society, pp. 211-215, 1986.

Abstract: The availability of stereophotometrically recorded human body data will permit us to better characterize three-dimensional shape, and to develop statistical techniques to take advantage of these mathematical characterizations. We have used whole-body data sets to simulate surface shape changes during body movements, and to provide surface contours for the design of anthropomorphic crash test manikins. Higher density face data are currently being used for surface contour comparisons, landmark spatial distribution analyses, and subregion delinations.

217. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1986 ASTM Publication Code Number (PCN) 04-900000-55 ISBN 0-8031-0461-8	Anthropometric Methods for Improving Protection	Robinette, K.M.

Source: Performance of Protective Clothing. ASTM STP 900, R.L. Barker and G.C. Coletta, Editors, American Society for Testing and Materials, Philadelphia, 1986.

Abstract: Many jobs involve contact with dangerous materials or hazardous environments requiring workers to wear various types of protective clothing and equipment. The fit of these items can directly affect both the worker's performance and the degree of protection provided and is, therefore, of paramount concern. Often, a stringent conformity to the body is required to afford the necessary physiologic protection and minimize degradation of performance. Traditional sizing practices are proving inadequate for protective wear in many instances; however, anthropometric analysis can be a very effective means of resolving the sizing and design problems. An anthropometric sizing analysis is based on the concept of dividing the population into subgroups of individuals who are similar for one or two relevant body size dimensions, then analyzing the remaining anthropometric data for each subgroup to arrive at appropriate dimensional design values. In this paper, the development and use of anthropometric programs for personal protective clothing and equipment is discussed.

218. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
1986	Three-Dimensional Summarization of Face Shape	Zehner, G.F.

Source: Proceedings of the Human Factors Society - 309th Annual Meeting - 1986, The Human Factors Society, pp. 206-210, 1986

Abstract: This paper describes the first year's progress in a three-year U.S. Air Force research project aimed at defining and summarizing the shape of the human face. These types of data are needed to enhance the fit and performance of protective equipment designed for the human body. Described are three-dimensional laser measuring systems, subject alignment and coordinate reference systems, angular statistical methods for summarizing points in space, principal component analysis of head cross sections, and data display and computer graphics development.

219. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-87-019 March 1987 AD A181 694	Annotated Bibliography of Psychomotor Testing	Ervin, C.

Abstract: An annotated bibliography of 67 publications in the field of psychomotor testing has been prepared. The collection includes technical reports, journal articles, papers presented at scientific meetings, books and conference proceedings. The publications were assembled as preliminary work in the development of a dexterity test battery designed to measure the effects of chemical defense treatment drugs.

220. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-87-034 September 1986	Development of a Standard Dexterity Test Battery	Robinette, K.M., C. Ervin & G.F. Zehner

Abstract: Numerous commercially available dexterity tests were evaluated for use in a standardized dexterity test battery to be used to assess the effects of chemical defense treatment drugs on manual performance. Twenty-six of these tests were administered to 118 subjects (60 females and 58 males). Factor analysis was used to identify tests which appeared to measure similar skills. The number of tests in the battery was reduced from 26 to 7 by selecting one test from each identified skill group on the basis of factor loading, ease of administration, and equipment durability.

221. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-87-036 September 1986	A Manual for Administering a Standardized Dexterity Test Battery	Ervin, C. & K.M. Robinette

Abstract: This manual is the final product of an investigation which resulted in the development of a standardized battery of seven manual dexterity tests



to be used in assessing the effects of chemical defense treatment drugs on performance. A companion report details how the tests were selected: this manual describes how to administer them. The battery includes special instructions for the following tests: Purdue Pegboard Assembly, Aiming, Photoelectric Rotary Pursuit-Circle, Reaction Time, Nine-Hole Steadiness (two tests) and Tapping.

222. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-87-046 June 1987	Fit Evaluation of Female Body Armor	Zehner, G.G., C. Ervin, K.M. Robinette & P. Daziens

Abstract: The object of this research was to evaluate the current issue MS-1 (Natick) female body armor vest, and to examine design modifications which would enhance the protection level by improving the fit. Subjects in the study were 37 female Air Force police trainees selected to represent a range of body sizes found in the overall USAF population. The MS-1 and two commercially available vests were evaluated for fit, comfort, and coverage in a series of measurements and observations. On the whole, the MS-1 vest compared favorably with the commercial garments. Some design changes are suggested to improve fit and coverage.

223. REPORT NUMBER/DATE	TITLE	AUTHOR(S)
AAMRL-TR-87-047 June 1987	Chemical Defense Flight Glove Ensemble Evaluation	Ross, J. & C. Ervin

Abstract: Four chemical defense flight glove ensembles were evaluated for their effect on manual dexterity. Two- and three-layer combinations included in the study were: cotton liner/7 mil butyl/Nomex; cotton liner/12.5 mil epichlorohydrin butyl/Nomex; Nomex/7 mil butyl (no liner); and, Nomex/12.5 mil epichlorohydrin butyl (no liner). Fifteen male and 15 female subjects performed five dexterity tests bare-handed and while wearing each of the glove ensembles. Results indicated that, as expected, all gloved conditions produced significantly poorer performances than did the bare-handed condition and two-layer combinations resulted in consistently better performances than did the three-layer combinations. Although subjects' performances were least impaired by the Nomex/butyl 7 combination, the butyl 7 gloves tended to tear. For this reason, the two-layer combination of Nomex/epichlorohydrin butyl 12.5 appears to be the most practical ensemble.

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